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# URBAN SNOW HAZARD: ECONOMIC AND SOCIAL IMPLICATIONS

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F I N A L   R E P O R T

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## ABSTRACT

THE URBAN SNOW HAZARD: ECONOMIC AND SOCIAL IMPLICATIONS

The snowhazard is urbanized North America is small because snowfalls are frequent, recurring, and expected. The costs of adjustment are high, relative to other natural hazards, and the pattern of adjustments, public, are reasonably well organized. The damage pattern is one of active disruption rather than one of death and destruction. A method was developed for use in informing municipal decisions concerning what is, in the northern tier of states, an expensive public service.



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CHAPTER 1

# INTRODUCTION

Duane D. Baumann and Mark Blacksell

Snow and ice are responsible for considerable damage and loss of life each year in the United States and Canada.1/ The snowstorm which paralyzed Chicago in 1967 is testimony to the fact that our cities are extremely susceptible to the snow hazard.

Attempts at measuring the costs of the urban snow hazard are limited.2/ There has also been a paucity of meaningful research concerning the planning process of snow removal programs. What accounts for the variation in the kind and extent of snow programs among communities within somewhat different snow environments as well as similar snow environments? Who makes the decisions, what alternatives are considered, what size of storm is planned for, and how do public attitudes affect such decisions are some of the many questions which remain unanswered.

As with the hazards of drought and flood, the range of choice open to any community faced with the snow hazard can be classified accordingly: (1) Adjustments that modify the cause; (2) Adjustments that modify the hazard; (3) Adjustments that modify the damage-potential; and, (4) Adjustments to the losses (Table 1-1). Little can be done presently regarding the modification of the cause of a snow storm; cloud seeding techniques

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1/ According to the U.S. Weather Bureau, damage attributed to the snow hazard in the United States ranged from an absolute minimum of $1,502,550 in 1964 to a maximum of $738,841,500 in 1958. However, these estimates are based on the high and low estimates of the U.S. Weather Bureau for those storms which were deemed severe enough for publication in Storm Data, U.S. Weather Bureau, Department of Commerce, Washington, D.C.

2/ The American Public Works Association conducted a study which was designed to measure certain economic impacts of snow and ice, with the hope of prescribing solutions for the problem. See, American Public Works Association, Snow Removal and Ice Control in Urban Areas (Draft) Chicago, 1965.

have been largely concerned with hail suppression and precipitation inducement. Nevertheless, most communities have adopted some type of snow removal program but the adjustments that require changes in people's habits are woefully absent.

Table 1-1

Theoretical Range of Adjustments to the Snow Hazard

| Modify the Cause | Modify the Hazard | Modify the Damage Potential | Adjust to Losses |
|---|---|---|---|
| Cloud Seeding | Snow Removal | Snow Routes | Bear the Loss |
| | Chemicals on the Highways | Forecasting | Insurance |
| | Heated Streets | Parking Restrict. | Public Relief |
| | Snow Fences | Snow Tires and Chains | |

← Technological — Behavioral →

Like the flood hazard problem, there has been little research on non-structural alternatives in snow hazard control. But, unlike the urban snow hazard problem, research in non-structural alternatives in flood hazard is now being undertaken by the U.S. Weather Bureau, U.S. Corps of Engineers, and the Economic Research Service in addition to public and private institutions. In the case of the flood hazard, floodplain zoning had been largely neglected with emphasis on structural alternatives. Consequently, flood damage-potential has continually risen. Another example is found in community planning for future water supply where adjustments such as water-use restrictions and the pricing mechanism are adopted only during times of a water shortage crisis; the development of new sources, especially reservoirs, is a traditional response. Weinberg, Director of Oak Ridge National Laboratory, recognizes the dichotomy and concludes that:

> It is only by cooperation between technologists and social engineers that we can hope to achieve what is the aim of all technologists and social engineers--a better society, and thereby a better life, for all of us who are part of society.1/

The snow hazard also provides opportunity for further study into the role of crisis in decision-making in resource management. Are most plans and decisions made in response to crises? And, if so, are such plans and decisions less than optimal because of the constrictions of the emergency period. Do plans and decisions made during crisis remain unchanged until a greater crisis? Or, do crises awaken communities and induce planning for future design crises?

Insight will also be gained regarding the evaluation process, especially the role of uncertainty in projections. In the case of the urban snow hazard, an uncertain natural environment provides the greatest challenge. A comparison of annual variability for cities with average accumulations between ten and twenty inches, and those with more than twenty is striking. There the decision makers must cope with a snow environment normally characterized by two and three inch accumulations one year, and thirty to forty inches in another. As noted earlier, the extent of community adjustment is not directly related to the annual amount of snow; instead, there appears to be a critical amount to which communities respond, which is related more to community decision amking and perception. Analysis of other questions concerning the evaluation process of the snow hazard will be instructive. Are plans and decisions rewarding snow programs made in a system context with the costs and benefits of other public expenditures weighed accordingly? Or, are annual appropriations allocated more through the political mechanism rather than economic evaluation?

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1/ Alvin M. Weinberg, "Can Technology Replace Social Engineering," Bulletin of the Atomic Scientists, XXII (December 1966), p. 8.

The purpose of this research report is concerned with two problems of the urban snow hazard:

(1) To identify and measure the economic and social impact of the snow hazard in urban places; and,

(2) To identify the factors affecting community adjustment to the urban snow hazard.

The conceptual framework of this inter-disciplinary effort is described in Chapter 2. In the remainder of this chapter, the study sites and techniques of measurement are surveyed.

There were two main principles guiding the choice of study sites. First, it was considered essential to choose a group of cities, which would be representative of all the major snow environments in the Eastern United States. Second, all the cities chosen were of approximately the same size, so that there would be at least a modicum of comparability in the problems they had to face.

Following the work of Rooney,1/ three major snow belts were identified. They were differentiated simply by the amount of snowfall received and each formed an area, running roughly east to west across the country. The area of heaviest snowfall (60 inches plus) included New England and all those states sharing a common border with Canada; the middle area (60 - 20 inches) included all but the most southerly part of the Mid-West, northern Appalachia and the east coast as far south as Washington, D.C., the most southerly area (under 20 inches) comprised small parts of Illinois and Indiana, Tennessee, Kentucky, the Virginias and the Carolinas. At least two cities were chosen from each of these three zones so that some cross-reference and comparison was possible.

All the cities chosen were medium-sized, with populations of between

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1/ Rooney, J.E. Jr. The urban snow hazard in the United States: An appraisal of disruption. Geographical Review, Vol. 57, pp. 538-559.

100,000 and 200,000. It was felt that such urban areas were large enough to experience real problems due to winter snowfall, yet at the same time could be studied in depth with the resources at our disposal. In any case many of the nation's largest cities, such as New York and Chicago, have already undertaken independent examinations of the problems produced by snow. In the heavy snow area the cities of Utica, New York, and Worcester, Massachusetts were selected as the major sites, although some reference to Duluth, Minnesota was made in the study of manufacturing. In the medium snow area Canton, Ohio, and Rockford, Illinois, were chosen. And in the low snow area Evansville, Indiana, and Nashville, Tennessee were the primary sites, with some reference to Greensboro, North Carolina, in the manufacturing survey. The main climatic and socio-economic characteristics of all these cities are summarized in Table 1-2. As can be seen there is a wide variation in character, although from the figures for per capita value added by manufacture and per capita retail sales all would appear to be considerably more prosperous than the national average. However it seems reasonable to conclude that the range of cities was wide enough to preclude undue bias towards any particular type. Also, an independent effort, but utilizing the same methodologies and instruments, was undertaken by Paula Archer in Regina, Saskatchewan.

During the spring of 1969 nine detailed questionnaires were designed to collect information on various aspects of the urban snow hazard problem. (Table 1-3) The study sites for the intensive investigations include Evansville, Indiana and Nashville, Tennessee with low annual snowfalls; Rockford, Illinois and Canton, Ohio with medium annual snowfalls; and Utica, New York, Worcester, Massachusetts, and Regina, Saskatchawan with high annual snowfalls.

Contact by letters were sought and received the cooperation of the chamber of commerce, the mayor's office, the weather bureau in each of the

Characteristics of Study Sites
TABLE 1-2

| | Population 1960 | | Population Change 1950-60 | Negro | Population Characteristics 1960, Age | | Employment 1960 | | | | Income in families, 1959, 1960 Medium Income |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | per sq. mile | | | Under 18 | Over 65 | Total | In M. | In R. & W. | In white collar occupa-tions | |
| | | | % | % | % | % | | % | % | % | $ |
| U.S.A. | 179,323,175 | 51 | 18.5 | 10.5 | | 9.2 | 64,639,112 | 27.1 | | 41.1 | 5,660 |
| Evansville Indiana | 141,543 | 4,127 | 10.0 | 6.6 | 34.4 | 10.6 | 50,306 | 30.6 | 22.1 | 42.9 | 5,299 |
| Greensboro North Carolina | 119,574 | 2,460 | 60.7 | 25.8 | 35.4 | 5.8 | 50,721 | 29.5 | 20.2 | 46.5 | 5,845 |
| Nashville Tennessee | 170,874 | 5,933 | 10.1 | 4.8 | 31.8 | 10.3 | 67,068 | 20.6 | 19.5 | 35.5 | 3,816 |
| Canton Ohio | 113,631 | 7,946 | -2.8 | 9.7 | 33.0 | 11.8 | 41,640 | 43.4 | 18.7 | 36.9 | 5,736 |
| Rochford Illinois | 126,706 | 5,109 | 36.4 | 4.2 | 34.5 | 10.3 | 51,820 | 44.6 | 18.9 | 45.5 | 6,865 |
| Duluth Minnesota | 106,884 | 1,620 | 2.3 | 0.5 | 34.1 | 12.5 | 37,169 | 19.2 | 22.7 | 48.5 | 5,877 |
| Utica New York | 100,410 | 6,276 | -1.1 | 3.1 | 30.3 | 13.9 | 37,682 | 30.4 | 18.5 | 46.2 | 5,873 |
| Worcester Massachu-setts | 186,587 | 5,016 | -8.3 | 1.1 | 30.2 | 13.6 | 72,743 | 37.9 | 18.6 | 44.4 | 5,804 |

M. Manufacturing
R. Retail
W. Wholesale

Characteristics of Study Sites (Continued)
TABLE 1-2 (Continued)

| | Manufacturers 1963 | | | | Retail Trade 1963 | | | Climate | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Establishments | | Value added by manufacture | Per capita value added by M. | Total est. | Sales of all Est. | | Mean Temp. | | Mean Annual | | |
| | Total | With 20 or more employees | $1,000 | $1,000 | | Total $1,000 | Per Capita $1,000 | Jan. | July | Precipitation in inches | Wind Velocity | Snow in inche |
| U.S.A. | 311,931 | 102,286 | 192,330,126 | 1.1 | 1,707,931 | 244,201,777 | 1,361 | | | | | |
| Evansville Indiana | 203 | 82 | 209,646 | 1.5 | 1,396 | 219,556 | 1,551 | 34.2 | 78.3 | 41.45 | 8.4 | 11.1 |
| Greensboro North Carolina | 253 | 118 | 266,544 | 2.2 | 1,253 | 230,878 | 1,931 | 39.7 | 77.3 | 42.16 | 7.8 | 7.7 |
| Nashville Tennessee | 501 | 223 | 330,731 | 1.9 | 2,419 | 445,475 | 2,607 | 39.9 | 80.2 | 45.14 | 7.6 | 9.0 |
| Canton Ohio | 204 | 77 | 285,544 | 2.5 | 1,173 | 192,756 | 1,696 | 27.3 | 71.6 | 36.43 | 10.0 | 37.4 |
| Rockford Illinois | 424 | 162 | 398,454 | 3.1 | 1,310 | 262,212 | 2,069 | 22.0 | 74.2 | 35.62 | 9.6 | 34.7 |
| Duluth Minnesota | 128 | 44 | 90,837 | 0.8 | 951 | 158,329 | 1,481 | 8.7 | 66.0 | 28.97 | 12.2 | 66.7 |
| Utica New York | 146 | 59 | 145,003 | 1.4 | 1,168 | 150,025 | 1,494 | 21.0 | 70.1 | 41.31 | NA | 67.4 |
| Worcester Massachusetts | 537 | 218 | 285,417 | 1.5 | 1,725 | 311,156 | 1,668 | 24.0 | 69.8 | 45.41 | 11.1 | 60.0 |

Table 1-3

Instruments of Data Collection

| | Attitudes Toward Snow Hazard | Economic Losses from Snow Events | Administrative Adjustment to Hazard | Weather Forecast and Perception of Hazard Severity |
|---|---|---|---|---|
| 1. Public Opinion Questionnaire Telephone Interview (approx. 50 at each of eight cities) | X | | X | X |
| 2. Public Opinion Questionnaire Mail (approx. 200 at each of eight cities) | X | X | X | X |
| 3. Street Superintendent Operations Questionnaire (1 interview at each of eight cities) | X | | X | X |
| 4. Street Department Financial Questionnaire (1 interview at each of eight sites) | | X | X | |
| 5. Retail Store Questionnaire (minimum of 10 at each of eight cities) | X | X | X | |
| 6. Manufacturing Firm Mail Questionnaire (all firms employing over 100 persons in each of eight sites) | X | X | X | |
| 7. Manufacturing Firm Interview Questionnaire (minimum of 10 firms in each of eight sites) | X | X | X | |
| 8. Nation wide Street Superintendent Mail Questionnaire (all U.S. cities of 25,000 pop. which experience snow) | X | X | X | X |
| 9. Public Opinion Mail Questionnaire (follow-up of Summer Telephone Interview) | X | | X | X |

the study sites. Thus local interest and cooperation were assured.

A three-person interview team undertook a summer-long trip which started in Evansville, Indiana and terminated in Worcester, Massachusetts. Five days were spent collecting the information at each of the sites in the U.S. Data collection at Regina was completed by August 1, 1969, a research assistant from the University of Toronto, Paula Archer, under the direction of Dr. Ian Burton.

# CHAPTER 2

## CONCEPTUAL FRAMEWORK

Clifford Russell

Man lives in a natural world in which nothing is constant and nothing is certain; so he must confront, at every turn, events occurring according to the outcome of celestial gambles for which he doesn't even know the rules. Fortunately, this world appears to have a good deal of inertial stability, so that the events tend to cluster in certain "normal" areas, and the probability of occurrence for deviations of a given size decreases as that size increases.1/ For a given class of events (for example, rainfall, temperature or even number of poisonous snakes per square mile) the values of the median will generally vary widely from place to place, but the indigenous population in each place will have adapted to the normal world it faces. Thus, the housing, clothing and hunting practices in traditional eskimo culture are geared to very low average temperatures, while the desert Bedouim of North Africa and the Arabian Peninsula have adapted to very high daytime temperatures and very low annual rainfall. In this country, the farmers of the humid East depend heavily on natural precipitation while in the arid West, spray or canal irrigation must be the order of things if other than very hardy

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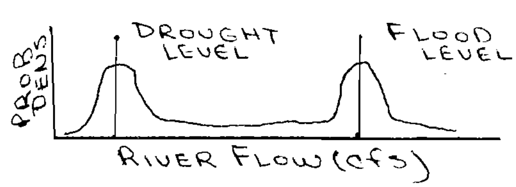
1/ This situation may be contrasted in the imagination with a world in which many natural events had probability density functions which were peaked at two extremes (bimodal), i.e., if both drought and flood were more probable than the mean flow. Thus:



beans or grasses are to be raised.1/

And so "hazards" are defined for a particular place by, in the first instance, reference to the long term "normal" events and the pattern of adaptation to these normal events. Thus, in a loose sense, extreme events from the local probability density functions constitute natural hazards for the local population. (For example, if our Eastern farmers experience a year in which total precipitation is equal to the normal in the arid West, they will suffer crop losses unless they are able to arrange for an emergency irrigation source and delivery method). But this is not a very satisfactory approach for two reasons. First, it forces us to specify some arbitrary level (or levels) of probability above which events are "hazards" and below which they are not. Second, and even if we were willing to make these choices, the definition leads us nowhere if we are interested in studying and affecting policy decisions dealing with "natural hazards."

Of more use is an approach which begins by recognizing that while a group's broad cultural adaptation is to the median events of its natural world, it has available in most instances shorter or longer run adjustments by which it can mitigate the impact of extreme events. Thus, the same natural event will affect groups differently, even in the same narrow geographic and cultural area, depending on the adjustments each

---

1/ The adaptability of a group depends, of course, on its income and on available technology. Thus, while our normal ways are ill suited to survival in the desert, by spending enough money we can create artificial islands of temperate, well watered climate through air-conditioning, and sea-water desalination. Whether these efforts are "worth it" is a question very similar to the one we discuss below in relation to hazards.

has made in the face of that particular aspect of uncertain nature. (A farmer with a storage pond is in better shape to meet a rainfall shortage than one without.) And so, whether or not we define a particular level of natural event to constitute a "hazard" has no importance for policy decisions. The important things are: The probability density function for the natural events; the range of available adjustments and their costs; and the effectiveness of the adjustments in reducing losses to the community. The fundamental policy question is: What level of adjustment to choose? And abstracting from problems of politics, distribution, etc., the answer is: That level which minimizes the sum of its costs and the remaining damages.1/ This proposition is the heart of the framework we apply to the urban snow hazard in this report, and it will be worthwhile to devote additional space to discussing and amplifying it.

We illustrate the basic proposition in Figure 2-1 where we show costs and (expected) damages for some unspecified hazard as functions of the chosen level of adjustment to that hazard.2/ We also draw in the curve representing the sum of costs and losses and indicate by A* the level of adjustment at which that sum is minimized. If we write costs and damages as functions of adjustment, C(A) and D(A) respectively, the

---

1/ Since we are dealing with uncertainty, this criterion, at its simplest, must be couched in terms of expected damages as we show below.

2/ For now we abstract from the problem of choosing one or a combination of related adjustments and concentrate on the choice of the appropriate level for a single possibility.

OPTIMAL ADJUSTMENT CHOICE

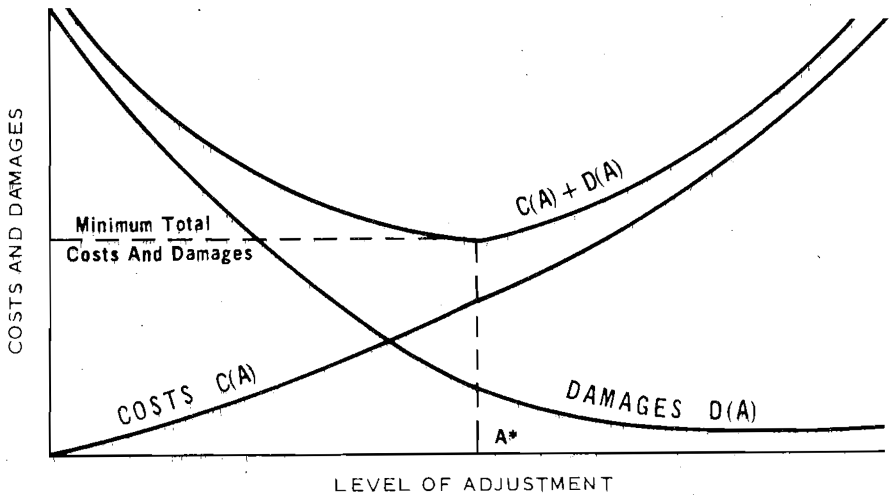



FIGURE 2-1

simple algebra of the problem may be briefly stated as:

$$\text{Min} \quad C(A) + D(A) ; \qquad (2\text{-}1)$$

with first order conditions:

$$\frac{dC(A)}{dA} = - \frac{dD(A)}{dA} . \qquad (2\text{-}2)$$

In words, this condition is: A necessary condition that A* be the optimal level of adjustment is that at A*, the marginal costs of additional adjustment are just equal to the marginal damages avoided by undertaking further adjustment. Thus, a first important point to note is that for decision-making purposes, we are interested only in the damages which can be affected by the contemplated adjustment. Thus, for example, in relation to urban snowfall, if the adjustment of interest is the level of snow removal capability maintained by a city street department, the losses resulting from snow accumulation on utility wires and tree branches, and from heart attacks among sidewalk shovelers, are irrelevant.1/ Of interest are damages in the form of increased worker absence, increased travel time, increased risk of accident, etc., attributable to accumulation of snow on city streets.2/

In order to understand better the mechanism behind the simple curves presented so far, it is worth considering an expanded but still general

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1/ Except, of course insofar as heart attacks can be related to the city's plowing practices in repeatedly filling in private driveways, etc.

2/ Strictly speaking, it is the reduction in damages as the level of adjustment is increased that is of interest. Thus it does us no harm to know, for example, that total damages (relevant and irrelevant) in the absence of adjustment are D if we also know that these are reduced by adjustment according to a function R(A). Then the first order condition is $\frac{dC(A)}{dA} = \frac{dR(A)}{dA}$ and the absolute size of D is irrelevent.

model. On the one hand, we assume that nature produces events, y, according to the probability density function f(y), one each time period. (We abstract from potential problems of serial correlation in the events.) The events y produce for any given level of adjustment, A', a physical impact I', on the affected human society according to the relation I' = g(A',y). This physical impact may in turn, we assume, be translated into damages for the time period, which we shall write as D(I). If we assume that the costs of implementing any adjustment level, A, are known to be C(A) per period (perhaps the per-period-equivalent of the capital costs of A plus the operating costs for running A during a period), we already have one half of the required information.

Obtaining the other half, the relation we have written, D(A) is somewhat more complicated. Since damages are indirectly a function of the adjustment level, we may write:

$$D(I) = D\left[g(A',y)\right] \qquad (2\text{-}3)$$

and making use of the probability information we have about the events, y, we may find the expected damages for given adjustment, A', as

$$E\left[D(A')\right] = \int_{-\infty}^{\infty} f(y)D\left[g(A',y)\right]\,dy \qquad (2\text{-}4)$$ 1/

In the case of any actual hazard, of course, there will almost certainly be a number of adjustment possibilities open, some of which will

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1/ Since this operation may be performed for any number of levels, A', it is possible to trace out a curve relating expected damages per period to adjustment level. This is the curve we have referred to above by the shorthand label, D(A). In practice, it is likely that the probability information will be in a form making analytical integration impractical.

be mutually exclusive, but others of which may be used in combination.1/ In addition, the hazard we refer to in the singular may have several dimensions, all present in the natural event, all related to damages, and all affected by specific adjustments in different ways. For this general case it is easy enough to write down the formal analogs of our earlier expressions 2-1 and 2-2, but it may be quite another matter to obtain and combine information on several adjustments, several hazard dimensions and the resulting physical impacts and damages in order to obtain the expected damage surface $D(A_1, A_2, A_3, \ldots)$.2/ Damage functions themselves may be difficult to express in dollar terms, since for more hazards, loss of human life or the infliction of pain and suffering may constitute a significant part of the problem.3/

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1/ For some purposes it may be useful to think of adjustments as falling into one of three broad classes: those that alter natural variation itself; those that moderate the impact on man of undiminished variation; and those that aim at redistributing losses within the affected group (or at spreading losses over a wider group).

2/ In the study of the flood hazard, for example, Gilbert White and his collaborators have identified a number of potential adjustments, including structural measures (such as dams, dikes, and flood walls), individual flood-proofing of structures, and flood-plain zoning. (See, for example, Gilbert White, Choice of Adjustment to Floods, Department of Geography Research Paper No. 93, University of Chicago, 1964.)

A noteworthy attempt to deal with the optimizing problem reflecting these major alternative adjustments was made by L. James, and reported in "A Time Dependent Planning Process for Combining Structural Measures, Land Use and Flood Proofing to Minimize the Economic Loss of Floods," Report EEP-12, Stanford University Institute in Engineering-Economic Systems, 1964.

3/ To admit that this problem of valuing human life is difficult is not to say that it is impossible to solve or that it is morally reprehensible to try. Every day our legislatures make implicit judgments about the value of human life--in voting on public health insurance, drunk driver legislation, and pollution control measures. One alternative for hazard research aimed at influencing policy is to report the implications of several alternative valuations.

Another set of problems calls into question, however, the usefulness of any exercise based on the determination of an economically efficient optimum. These problems focus on what might be termed broadly the "political situation." Thus, any set of adjustments and decisions about funding their costs will imply a certain distribution of costs and damages (and damages avoided) over the individuals and sub groups of the overall society affected by the hazard. Decision makers, whether idealized "managers" or legislative bodies, will be sensitive to this distribution in combination with the political "weight" they perceive as attaching to each of these groups. However one models the political decision process, it is unlikely that the economically efficient solution will be of much relevance.1/

In addition, of course, the adjustments that are perceived as possible by the public and their representatives will be to a greater or lesser extent limited by the prevailing traditions of the society. Of particular importance in this regard is likely to be the society's view of its relation to nature--whether it stands as nature's master, partner, or subject.2/ Thus, for example, our society tends to view itself as nature's master and tends to resist adjustments which seem to

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1/ For related views of this process (that nonetheless diverge in significant particulars), see E. Haefele, "Environmental Quality as a Problem of Social Choice," presented at the June 1970 RFF Conference, Environmental Quality and the Social Sciences: Theoretical and Methodological Studies, June 16-18, 1970 (mimeo); and R. Dorfman, "General Equilibrium with Public Goods" in Public Economics, Margolis and Guiton (eds.) (New York: St. Martin's Press, 1969).

2/ See C. Russell, "Losses from Natural Hazards," Land Economics, November 1970.

"give in" to nature (e.g., closing down a city for a day or two, rather than frantically trying to keep up normal work routines and traffic movement during and after large snowfalls).

To give these political and cultural questions their full due within our conceptual framework would be a large project in itself, but we can suggest schematically where they would fit in to a larger decision model taking into account a number of alternative adjustments. In Figure 2-2 we provide such a schematic, also calling attention there to the possibility that adjustment alternatives may differ in the time horizon over which decisions about them must be made. Thus, for example, some alternatives, such as dikes, levees and storage reservoirs for flood control involve commitment of resources for as much as 50 or 100 years. In the short run, on the other hand, decisions must be made about operating policy for the reservoirs--when and how much to spill to make room for expected heavy flows; whether or not to add sandbags to levee tops; whether or not to evacuate the "protected" population. There will, in general, exist technical relationships between long and short-run alternatives, as well as within the two sets themselves, adding another layer of complexity to the policy problem.

## A MODEL OF THE DECISION PROCESS FOR ADJUSTMENT TO HAZARD

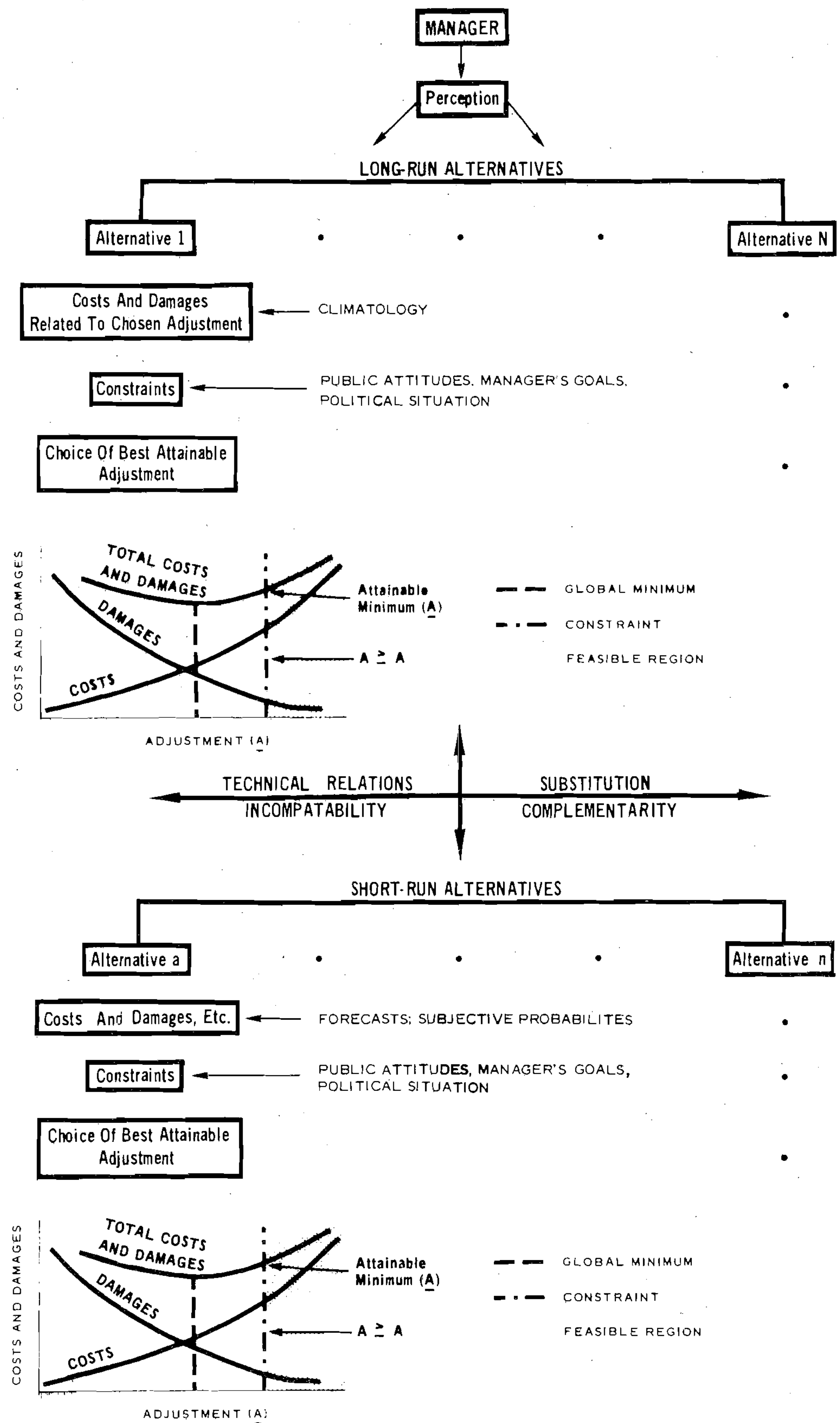


FIGURE 2-2

Application of the Framework to the Urban Snow Hazard

We have attempted to use the conceptual framework just described both as an aid to coordinating the research of the several authors and organizing this report, and as the basis for a quantitative investigation of a particular adjustment to urban snowfalls. We have done this in full knowledge of the general weaknesses already discussed and with developing appreciation of the complexity of the problem and the difficulty of gathering data about it. In this section we discuss the general identification of elements of the urban snowfall problem with elements of the model. In the next chapter we consider in more detail the range of adjustments open to the municipal decision makers facing this problem, and in Chapter 4 we present some results of attempting to quantify costs and damages related to the overwhelmingly popular adjustment to snowfalls, street clearing.

As noted above, adjustments to a particular hazard may be placed in three broad categories: those intended to dampen natural variation; those intended to soften the impact on human society of undiminished variation; and those intended only to redistribute costs and losses from given events. In the case of urban snowfall, there appear to be three major adjustment alternatives. First, weather modification aimed at changing the amount or location of snowfall (damping natural variation) as a possibilty, though not at present a highly developed one.1/

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1/ Some success has been reported in shifting snow storms into sparsely populated areas along the New York State shore of Lake Erie.

Second, given the present pattern of snowfall, a city can opt to attempt to keep its life as near normal as possible by clearing streets through plowing, chemical application or heating of road surfaces.1/ Given that a fundamental desire is to maintain the normal pace of the city's life, the street-clearing adjustment reduces damages and increases costs. The remaining damages tend to be borne by individuals in their capacities as frustrated commuters or shoppers, while the costs are shared among tax payers generally in relation to assessed property values.

A third basic mode of adjustment seems, however, to be possible; this would involve less interference with the physical impact of a snowfall and the institution of a new normality for snow days but would still basically fall into the second category. Instead of trying to remove the snow essentially as fast as it falls, the city would either wait for higher temperatures to remove it naturally (in areas of low snowfall and high normal daily winter temperatures) or attack at a slower pace than presently. Meanwhile, not only schools but also shops, offices, government agencies, and even many production facilities might be closed down. Provisions would have to be made for emergency vehicles and services. (This would probably involve purchase of special vehicles, but could be less troubling than it might appear because of the presumed absence of the stalled and skidded autos of unlucky commuters.) In addition some continuous process facilities such as steel mills might be too expensive

1/ Abrasives such as sand and cinders are still applied as a part of the general clearing operation, though their use seems to grow progressively less common as they are replaced by chemicals which combine some immediate traction improvement with longer-term removal.

to shut down. In any event, the damages would equal only whatever real losses in production(value-added) were involved after allowance for postponement of production (and sales) beyond the time of the snow,[1/] and would be borne, at least initially, by the owners of the factors of production involved. On the other hand, it seems reasonable to think that substantial offsetting benefits from unanticipated leisure, snow-based recreation experiences and even the aesthetics of undisturbed snow scenes, would flow from this adjustment.

An ideal analysis of the urban snow hazard would look simultaneously at all three broad categories of adjustment (realizing that weather modification could be used in conjunction with either of the other two, but that the choice between striving to maintain normal activity and shutting down after heavy snow is essentially dichotomous). This would, however, involve some extraordinarily difficult estimation tasks, particularly involving the costs and physical impact of weather modification, and the damages (net of recreational, aesthetic and emotional benefits) of granting more snow days. We have chosen to be less valiant but more realistic and to confine ourselves to considering the street-clearing adjustment.

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1/ The calculation of losses depending on the accounting point of view adopted (e.g. local or national) and the effect of allowing for transferral or deferral of production and sales are discussed in C. S. Russell, D. G. Arey, and R. W. Kates, Drought and Water Supply: The Implications of the Massachusetts Experience for Municipal Planning (Baltimore: Johns Hopkins Press, November 1970).

To begin at the beginning, then, in speaking of a snowstorm of so many inches in so many hours, it is clear that the major dimensions of interest are those of rate and total depth of fall. There are, however, a number of other significant dimensions in determining the extent of human loss associated with the storm. Thus, for example, the temperature, the wind speed and time of day and day of week all have some impact on losses. Temperature determines whether the first layer of snow will turn to a glaze of ice under pressure of traffic and is important in determining the density of the snow on the ground. Wind determines the extent of drifting (in combination with temperature). And snow fall on Sunday morning is less dangerous than one beginning in the middle of a weekday afternoon.

We shall submerge the dimensions of wind speed and timing, and treat temperature only roughly, concentrating on the <u>hourly</u> rate of fall as the important dimension of the storm. This decision, in turn, suggests a natural measure of the level of municipal adjustment: the rate at which snow can be removed from the city's streets in inches per hour.1/ It seems reasonable to expect that since the aim of the city government is to maintain a normal flow of traffic, any net accumulation of snow will cause damages. The shortest period which appears to be practical

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1/ As we have already noted, an inch of snow in one storm can be far heavier than the same depth in another, and an average fall of one inch gives much greater trouble if it is drifting than if it is not.

for analysis of this effect is the hour, since the most detailed precipitation data are available for no finer time breakdown. Within these constraints, the basic tasks involved in applying the model to a particular city are:

(i) The translation of snowstorms (either historical or synthetically generated1/) into records of hourly snow accumulations for various assumed levels of removal capability. (This amounts to determination of I=g(a,y) in our earlier notation.)

(ii) Translation, in turn, of the impact (snow accumulation series) into damages by taking account of the effect of snow on average speed (and hence costs) of travel, risk of traffic accidents, worker absence and disruption of shopping plans and commercial traffic activity. D(I)

(iii) Estimation of the expected value of damages for some planning period, say a year, on the basis of the historical record of snowfalls in the city.2/

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1/ See, for a discussion of synthetic reproduction of time series of natural events, M. M. Hufschmidt and M. B. Fiering, Simulation Techniques for Water Resource Systems (Cambridge: Harvard University Press, 1966).

2/ How this is done depends to a great extent on what kind of data on storms and damages is used in estimating losses. Below we use fairly long historical snowfall records and a "synthetic" model for generating losses attributable to snow accumulations. Thus, we can estimate the annual expected loss very simply from the series of annual loss figures our method produces. If, on the other hand, losses were estimated on a micro level (interviews, traffic measurement, etc.) for a single storm, the estimation of expected losses would require us to find the probability function for natural events, f(y). In the case of snow fall the necessary function would be quite complex because we could not be content with estimating the proportion of hours of any winter likely to have snowfall in the range $y_1$ to $y_2$ inches. The serial correlation of hourly falls (the storm effect) is extremely improtant in determining damages.

(iv) Estimation of the annual costs of maintaining and applying various levels of removal capability.

This last item raises further difficulties, however, for it is quickly obvious in studying snow removal costs and strategies, that many decisions which involve incurring costs and reducing damages are short run in nature, and while constrained to some extent by longer term choices of equipment levels, chemical stockpiles, etc., are flexible over a very wide range and subject to considerations of uncertainty of a somewhat different kind than these longer term decisions. It will be worthwhile to pause and consider these two aspects of municipal snow removal more carefully. Longer run decisions with respect to snow removal capability generally commit the city to courses of action for one year at a time. Thus, size of truck fleets, plow inventories and chemical stockpiles may be increased with relatively short lead time (depending on bidding and contracting laws and whether or not the equipment desired is standard manufacturers' stock). It may be more difficult to reduce the level of resource allocation to snow removal in the course of a year simply because markets in second-hand equipment are not very well developed. But in any case, equipment lives were estimated by interviewed managers to be between 5 and 10 years for most of the pieces used in snow removal,[1] so that normal attrition, with staggered purchasing, would permit reductions of one tenth to one fifth

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1/ Our respondents estimated truck lives to be 5 to 11 years; plows, 5 years; snow blowers, 10 to 15 years; front end loaders 5 to 10 years; chemical spreaders 5 years; and road graders, 20 years.

of the inventory each year. Chemical stockpiles may, of course, be varied over an even shorter period, but certainly by signing annual supply contracts, year-to-year adjustment is entirely feasible. Commitment to a given labor force size may be relatively long term for equipment operators and maintenance personnal because of union contracts on civil service rules. (But the laborers used for downtown street and sidewalk clearing can almost always be hired for a single storm.) All these decisions may reasonably be presumed to be made on the basis of long-run experience with snowfall in the particular city, especially with size of heaviest recorded hourly falls and accumulations from largest recorded storms. These decisions fix an upper limit to removal capability.

In the short run the decision problem is essentially one of determining what portion of the available snow removal forces will be required for a predicted storm and when to mobilize and deploy those forces. The weather forecasts upon which mobilization decisions are generally based may under or overestimate the amount of snowfall to come and may under or overestimate the time until the beginning of the storm. If mobilization is ordered and no storm occurs, considerable "wasted" labor costs will be incurred; while, on the other hand, if mobilization is too little or too late, the combination of storm and traffic snarls may prevent the city from ever really "catching up" and will generally result in much higher damages <u>and</u> removal costs than would timely action for the same storm.1/ This is the classic weather forecast problem as studied by Rapp and others at Rand.2/ An empirical study would require not only extensive information about costs of mobilization and damages from late or insufficient efforts, but more importantly, data on historical forecasting accuracy both as to timing and rate of snowfall. We did not feel able to undertake such a study with our limited manpower, time and funds, and in the empirical application below we concentrate on the long-run problem. But before going on to discuss this quantitative work, we turn to a more detailed discussion of the range of adjustments open to responsible parties in city governments.

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1/ The most famous recent case in point is the New York City disruption of 9-14 February 1969. That 15-inch storm, beginning on a Sunday, the 9th, resulted in chaos on Monday and the city was still digging itself out by Friday, the 14th. The major causes were generally conceded to be the 6-hour delay in imposing snow emergency conditions on traffic in the metropolitan area and the delay in removal-crew mobilization occasioned by a bureaucratic foul up. Contributing to the problem was an attempt by the financial district to open on Monday even though by then the entire area was hopelessly snarled.

On the next weekend, predictions for a second storm produced very rapid mobilization but proved to be wrong--at a cost of about $250,000.

2/ See, for example, R.R. Rapp and R.E. Huschke, "Weather Information: Its Uses, Actual and Potential," Memorandum RM-4083-USWB, May 1964, Rand Corporation, Santa Monica, California. This problem was attacked on a simpler level, but with specific reference to snowfall, by J.C. Thompson of the U.S. Weather Bureau: "The Snowfall Probability Factor," <u>The American City</u>, December 1959, pp. 80-88. Unfortunately Thompson's numbers were all purely for illustrative purposes. See also, Robert E. Helbush, "Linear Programming Applied to Operational Decision Making in Weather Risk Situations," <u>Monthly Weather Review</u>, March 1969, Vol. 46, No. 12, pp. 876-882.

CHAPTER 3

# RANGE OF ADJUSTMENTS

John Rooney

Residents of the Northern United States generally have strong opinions about snow and ice. Many have equipped themselves with snow gear, such as shovels, snow tires and chains, brooms, lugs, or of late, automated snow blowers. Virtually all have complained at one time or another about the quality of the public effort to cope with snow, but few have any notion of their monetary contribution to the effort. Some have even fled to snowless California, Florida, or the Southwest.

If we can view the current status of snow control as being indicative of public concern for the problem, we must conclude that the snow hazard is more imagined than real. For generally speaking we are still coping with snow and ice in the same manner that was characteristic 50 years ago. Granted, there have been new technological developments, such as snow melters, radiantly heated pavement, blowers, and except for chemicals, their adoption has been extremely limited. And only recently have concerted attempts been made to alter public behavior under severe snow conditions.

It is the purpose of this chapter to assess the current state of the art in the United States and to examine the rationale on which snow control programs are based. The range of choice concerning new program possibilities will also be analyzed.

## Current Programs

There are several published estimates of the annual public costs for snow and ice control. The American Public Works Association has cited the figure of $100 million per year, but considers this to be extremely conservative in light of salt costs alone. The same organization estimates per capita expenditures in the large snow belt cities to be in excess of one dollar, and to run as high as $15 in abnormally high snowfall years.1/ Public Works nonchalantly quotes snow and ice removal costs at $500 million annually.2/ Perhaps more meaningful is the statistice cited by the Salt Institute of Alexandria, Virginia. They claim that snow removal in the 33 Northern states accounts for 18 percent of total street and highway maintenance costs and for two percent of all highway expenditures.3/

There are myriad problems associated with data compilation of snow and ice control expenditures. Record keeping is not comparable from city to city and many snow costs are hidden or exaggerated within complicated city budgets. In general snow is treated as an emergency and record keeping is accorded a secondary priority. Treatment of equipment depreciation as a segment of snow control costs also varies markedly between cities.

Survey of Programs

Snow and ice control in the United States was examined via a questionnaire, sent to all communities of over 10,000 that recorded snow during the past ten years. Questions dealt with program administration costs, planning, and implementation. Also included was an equipment inventory and a probe of managerial attitudes. A total of 176 usable questionnaires were returned; coming primarily from the "snowbelt" states. Response from cities with a mean annual accumulation of less than twenty inches was sporadic. And many were incomplete.

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1/ "Snow Removal Costs," The American City, (December 1967) p.77.

2/ "Plowing and Loading Snow--One Machine Can Do Both," Public Works, (November 1968) p.96.

3/ H.R. Mallot, "Pre-Winter Planning is Important," Public Works, (August 1967) p.103.

Program Description

As expected, there was a great deal of similarity among programs. Most adjustments can be categorized as antiquated defense maneuvers with a bias toward the technological mass attack philosophy; abrasives and chemicals applied to icy surfaces, plowing after a given depth is reached, removal from central areas and deposition in less crowded areas. A few cities have gone beyond the traditional plows, graders, and trucks, and have opted for more sophisticated apparatus such as snow melters and blowers. Data provided by the Thermal Corporation demonstrates that adoption of melters has thus far been minimal, even though a strong case can be made for their long run profitability.1/ Radiant heated streets and intersections have only been installed in three of the responding communities.

The last several years have witnessed comparatively greater advancement on the behavioral front. The majority of communities now have ordinances which require certain actions to be taken under snow emergency conditions. Restrictions are commonly placed on parking, and many cities have designated snow emergency routes.2/

Utilization of snow tires, lugs, and chains are encouraged and in some situations required. Early dismissal of public sector employees and pressure for similar action regarding private workers is also exemplary of this trend.

Expenditures

Based on the survey data, per capita expenditures range from less than ten cents in a number of Southern cities, to a high of $24 at Holland,

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1/ T.E. Lucier, "High Speed Snow Removal," The American City, (September 1968) pp. 104-108.

2/ For a thorough discussion of snow arteries see: "The Problem of the Parked Car," Public Works, (August 1964) pp. 78-80.

Michigan. It is likely that the Holland figure reflects an atypical year, but there are several places in the $5 to $15 bracket (Table 3-1). A casual analysis of the expenditure data suggests that they are rough estimates at best. The extreme variations between communities with comparable economic bases and snow environments must in part be a function of different accounting systems. Waukegon, Illinois ($3.23) and Racine, Wisconsin ($0.87) are indicative of this problem. A comparison of the New Jersey contingent reinforces the difficulty of assembling reliable estimates of expenditures.

Organization

One measure of a community's snow control organization is the snow plan. The existence of a written plan generally coincides with a higher level of organization or at least suggests that the city is serious about its snow fighting effort. Of the responding communities, one half claimed to have a written plan (Figure 3-1). Cities with greater hazard certainly were more apt to have plans than those in transitional or low snowfall areas, but the correlation was suprisingly weak. Less than one half of the Missouri, Illinois, Indiana, and New York sites had plans. On the other hand, most of the cities across the snowbelt from Wisconsin to New Jersey claim to utilize written programs.

In recent years greater emphasis has been placed on hazard planning.1/ Sanding, salting, and plowing routes have been carefully identified and responsibilities for different sections of the city have been assigned. Strategy has been laboriously designed to cope with numerous contingencies within the constraints of the presently adopted technological capabilities. The result has been a general upgrading of snow control; a maximization of

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1/ A survey of the literature pertaining to snow control in The American City, and Public Works points out a trend away from the emphasis on various types of snow equipment in favor of planning and organization.

CITIES WITH SNOW REMOVAL PLANS (1969)


Figure 3-1

effort considering the inherent defects of the system.

Implementation

The nature and goals of snow control vary throughout the United States. Most snow control is comprised of sanding or salting, plowing, and removal. Only the degree of emphasis, timing, and efficiency vary. The declaration of snow emergencies, and the depth at which plowing begins are illustrative of this geographic variation. The snow emergency is now common in all regions. It consists basically of an alert system involving the public, police, snow control personnel, and the broadcasting media. The alert is triggered by an accumulation of a given magnitude (usually two or three inches) or the threat of a really serious storm. In most cities, restrictions on parking and travel routes are automatically invoked when the emergency is declared. However, in many urban areas the emergency is given little more than lip service with interagency cooperation and code enforcement at a minimum.

The effectiveness of snow control can be roughly measured by a spatial comparison of the depths at which plowing operations begin (Figure 3-2). Here the pattern is very clear. Virtually all cities in the Northern tier of states commence operations at depths of three inches or less. Some of the Northern communities wait until four to seven inches have accumulated, as do the majority of cities around the Ohio Valley. Most of the Southern respondents postpone action until the snow has ceased. This is also true in the West and Rocky Mountain area where plowing the dry, blowing snow has been proven ineffective.1/

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1/ For a discussion of this see: John F. Rooney, "The Urban Snow Hazard in the United States, an Appraisal of Disruption," The Geographic Review, LVII, (October 1967) pp. 538-559.

# DEPTH OF SNOW AT WHICH PLOWING BEGINS (1969)
(in inches)

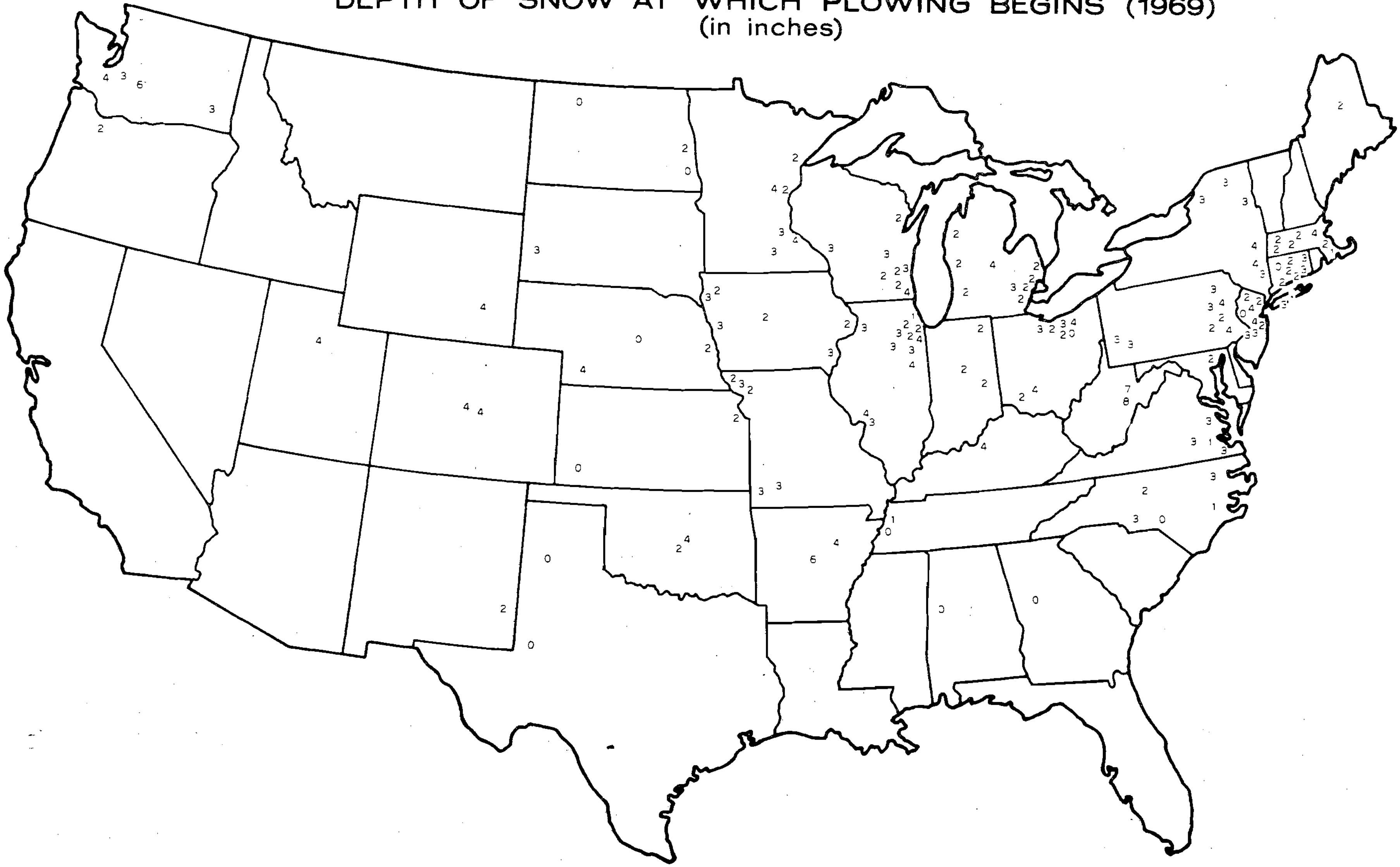

Figure 3-2

A better indicator of program magnitude is the percentage of streets which are plowed.1/ Again we see that complete clean-up is the goal in the North (Figure 3-3). Throughout the lower Midwest a 20 to 60 percent job is satisfactory. And in many communities only the main arteries are treated.

Plowing strategy is to some extent a function of post-storm weather expectations. Where snow is typically followed by long stretches of cold weather it is necessary to clear all streets. Hence, the strategy in the North is a long term one as opposed to the short term emergency measures in lower snowfall areas. And it is when the cold lingers after the snow in places like Tennessee and Virginia, that the really serious prolonged disruptions occur.2/

Interagency and Interurban Cooperation

One glaring weakness throughout most of the country is the lack of interagency and interurban cooperation. Greater reliance on behavioral alternatives such as parking, snow artery, and vehicle restrictions make enforcement vital to the success of snow control operations. Yet in many of the responding cities reference was made to poor enforcement of restrictions. Illegally parked vehicles were ticketed but not towed away as the

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1/ The responses concerning street plowing must be viewed with some skepticism. Many cities claim 100 percent coverage, an improbable figure considering their reported expenditures. The range in Connecticut was from 23 percent to 100 percent, in Iowa and Michigan from 20 percent to 100 percent, and in Ohio from 7 percent in Youngstown to 100 percent in Columbus. Per capita outlays were twice as great in Youngstown.

2/ For a discussion of the severity of disruption in low snowfall areas, see: John F. Rooney, "The Economic Implications of Snow and Ice" in Richard Chorley, ed., Water, Earth and Man, Toronto, Methuen, 1969, or ________, "Let's Be Objective About Snow Control," American City, Vol. 84, (October 1969) pp. 106-112.

## AVERAGE PERCENTAGE OF PLOWED CITY STREETS (1969)

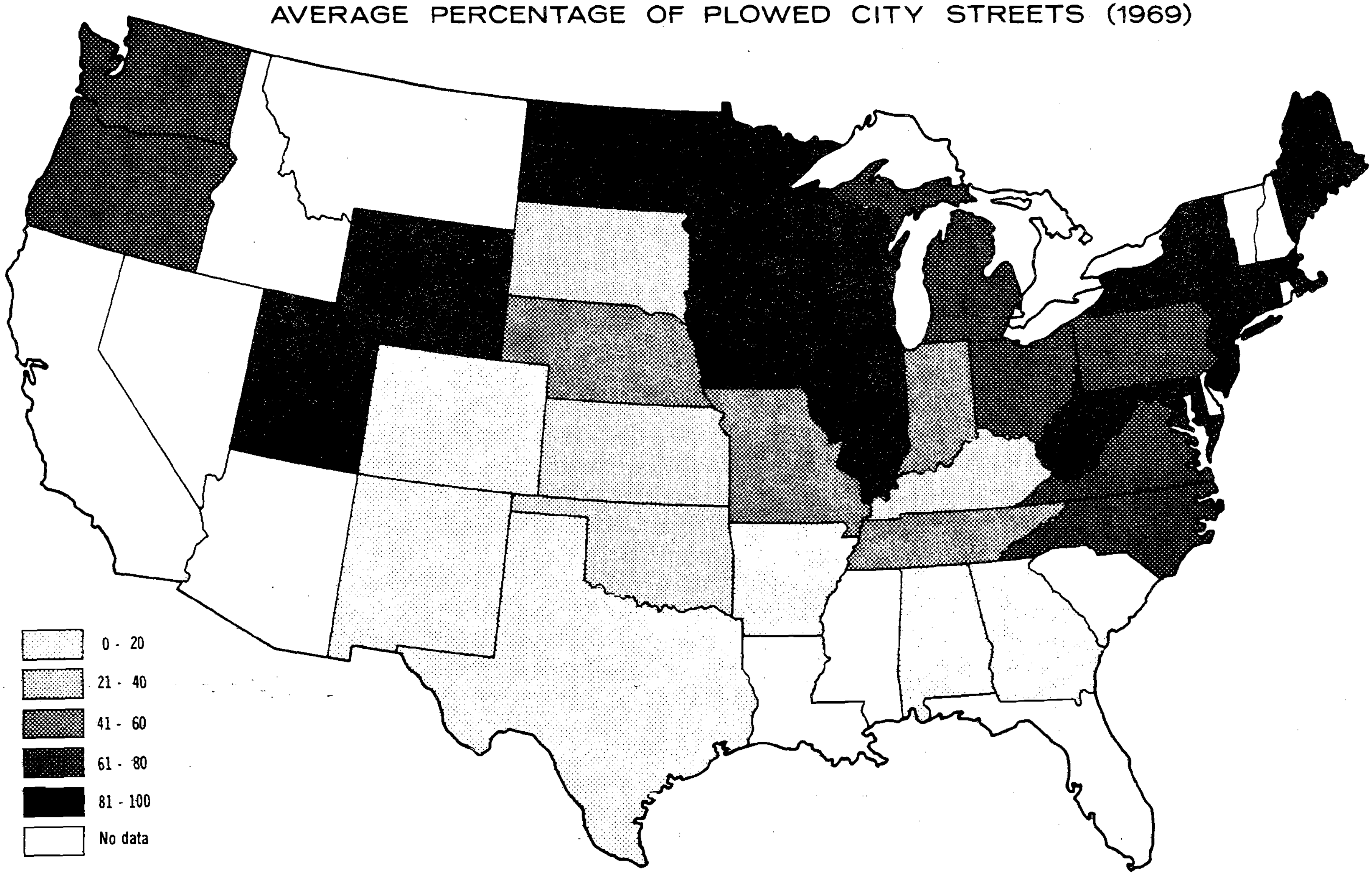


Figure 3-3

law required. In many cases motorists stalled on snow routes were not issued citations as should have been the case according to the snow ordinance. Rapid City, South Dakota is indicative of the problem. The community has a written snow plan calling for various parking restrictions. These restrictions however are largely ignored by the populace because they have never been vigorously enforced by the police department, thus impeding the effectiveness of the snow program.

Intercity coordination is perhaps the most crucial element where regional snow control is concerned. The majority (102 of 149 responding to the question) of cities queried stated that they did coordinate their programs with those of neighboring communities. However, a significant proportion of the large central cities failed to coordinate with surrounding suburbs. In fact, many cities were in active competition with surrounding urban areas. It is difficult to say whether this produces better or poorer levels of regional snow control. Communities in the Norfolk, Virginia area believe that competition has resulted in program improvement. Such competition may actually raise the level of snow control in some instances, but it cannot be denied that some degree of coordination (perhaps coordinated competition)would be more beneficial.

Assumptions Upon Which Snow Control Is Based

Knowledge of the snow environment is all too meager, even in some of our largest metropolitan areas. Most managers are ignorant or only vaguely aware regarding the probable occurrance of snow of various magnitudes in their cities. Terms such as a five or ten year storm are foreign to most public works officials, who prefer to evaluate the hazard by the number of times they expect to plow, sand, or salt each year. Their budgets are generally inflexible and like most municipal expenditures are geared to past experiences. Few cities have attempted to evaluate snow expenditures from even the simplest cost-benefit framework.

Managerial knowledge of annual snowfall is meager. Many of the respondents were in error by 25 percent or more in estimating annual snowfall in their cities. But perhaps this figure is of little significance when compared to storm frequency and storm severity expectations.

Expectations

We asked the snow control officials to comment on the types of hazard conditions they expected and on those with which they could not combat effectively. They were also asked about the type of storms which presented the greater difficulty.

Severe storm expectation varies markedly throughout the Snowbelt (Figure 3-4). A number of the managers from communities in heavy snow sections such as Minnesota, Wisconsin, Northern Illinois, Indiana, Ohio, New York, and Massachusetts said they expected storm accumulations of less than ten inches. In Connecticut anticipated levels ranged from eight to nearly thirty inches. Throughout the transitional snowfall zone of the South Central United States, there is little pattern. A similar situation characterizes the Plains and the Northwest. It is in these transitional areas where experiences of the immediate past (the last few winters) govern knowledge and behavior relative to snowfall. These environments of greatest uncertainty also provide the most difficult challenges for decision makers. And as stated earlier, most of them have adopted "hope and pray" strategies.

A blizzard was accorded the highest disruption rating by snow officials from all sections of the country (Table 3-2). Struggling with blowing snow was considered the most serious challenge to keeping transportation arteries open, particularly in areas where success was based on plowing and removing

ANTICIPATED STORM MAGNITUDES

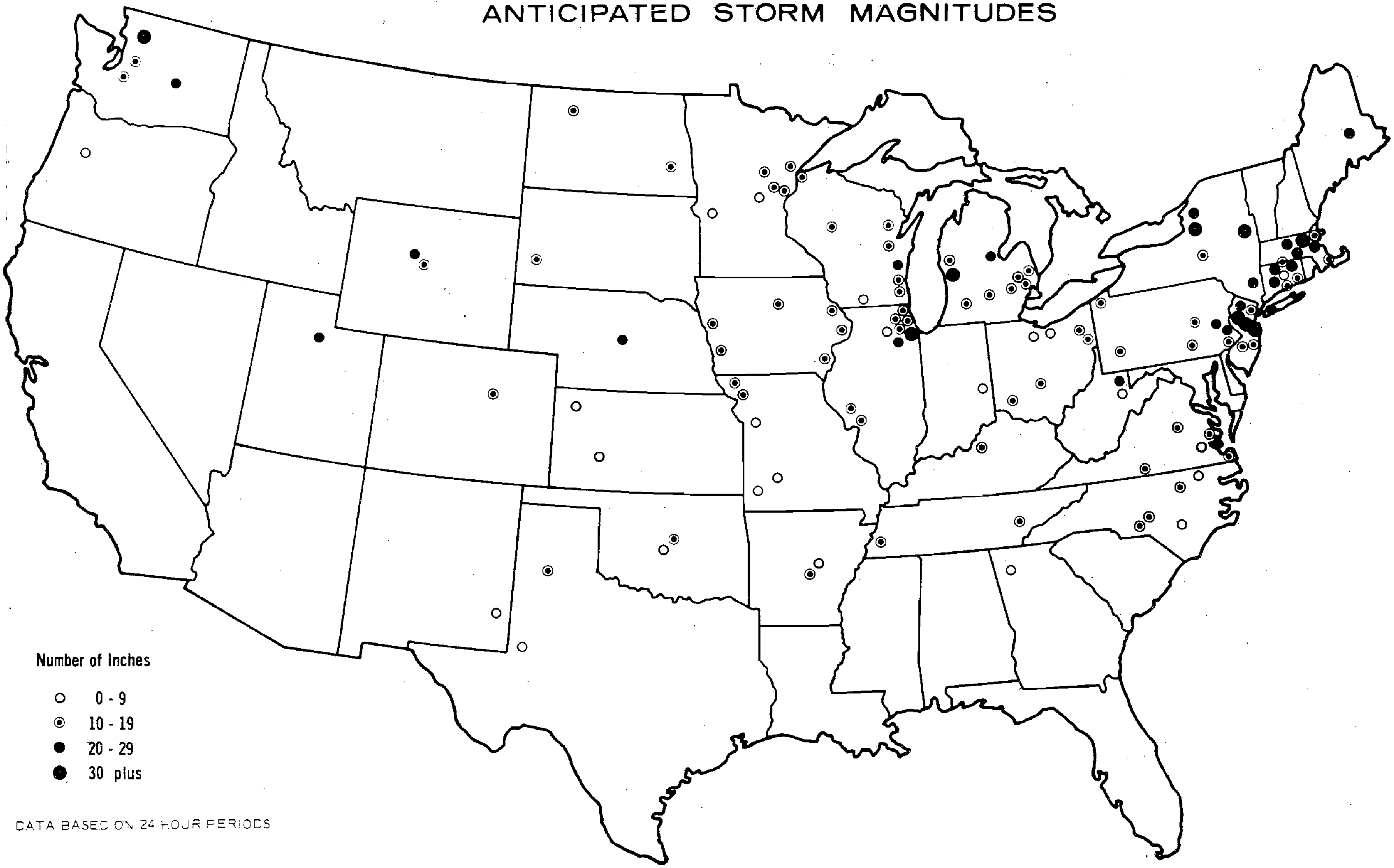


Figure 3-4

snow, i.e., the Northeastern and Midwestern sites. Although blizzard conditions are not officially recognized by the United States Weather Bureau until average wind speeds reach 35 miles per hour, added disruption begins to develop with winds of 10-15 miles per hour.1/

A previous study demonstrated the effect of wind speed in promoting disruption at six study sites.2/ On the street interviews also complemented the attitudes of the managers concerning the severity of the blizzard problem.

Snow and ice storms were also considered a serious problem by the municipal respondents. Proportionately the greatest concern for these was voiced in the East, particularly in an area from Virginia southward. Again like the blizzard, most snow control programs are not geared to effectively combat anything but pure, stable snow. Thick ice does not respond readily to salting, nor does blowing snow to plowing. Thus, most programs break down when confronted with either of these conditions with the result -- severe disruption.

Several of the respondents cited abandoned cars or equipment malfunctions as their most serious problem. The former are certainly a function of blizzard conditions, snow and ice combinations, or extreme cold, and must be evaluated as such. However the presense of abandoned vehicles suggests poor organization and a high dependence on technological solutions, rather than behavioral ones, a fact which in large measure illustrates the basic weakness of snow control.

Recent Improvements and Innovations

The last decade has witnessed an increased emphasis on planning and organization. The American City, which must be regarded as the forum for

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1/ The effect of wind speed is dependent on the moisture content of the snow, topography, and the type of structures along the routes of question.
2/ For a detailed discussion see: Rooney, op. cit., pp. 551-554.

those involved with urban snow problems in North America, has published over 170 articles on the subject since 1960. The bulk of them have been of the case study type describing the plan of attack in such places as Praire Village, Kansas; Moscow, Idaho; and Oshkosh, Wisconsin. It is possible, however, to categorize these studies by topic such as planning, equipment, techniques, costs, public behavior, and inventory. In so doing a trend from 1960 to the present is faintly discernible. Concern has generally moved from equipment to planning, to public behavior, and back to equipment again.

Apparently this reflects some basic changes which have occured. Planning is now an integral part of all the better programs. Most of the communities with better programs have also instituted regulations which govern behavior relative to parking, automotive equipment (tires and chains), shoveling, and patterns of movement (snow routes). With this established, the trend has reverted to a pre-occupation with equipment. Several recent articles have dealt with snow melting devices and their adoption by a number of snow belt cities. The use of sidewalk plows and snow blowers has also been given coverage, and reference has even been made to thermally heated transportation routes. The fact remains though that the vast majority of articles have introduced very little in the way of new approaches to solving the snow problem.

<u>What Are the Possibilities</u>

Notably absent from the literature are references to the extensive use of weather modification, radiantly heated streets, emergency snow vehicles, or the declaration of "snow fests".

<u>Weather Modifications</u>--Most of the research in weather modification has centered on triggering precipitation through various cloud seeding operations. Conversely some work has been done on precipitation repression, particularly over leeside lake locations. The snow control literature indicates little

interest in weather modification as a potential hope for the future. Nor has the North America Snow Conference given more than cursory attention to this alternative.

Although weather modification is an inexact art at the present time, it would seem that far sighted snow control planners would be well advised to consider the possibilities, as well as the social and economic impacts associated with them.1/

Radiant Heat--Infrared overhead lighting and radiant heating would appear to provide an answer for some snowbelt cities, particularly for hilly thoroughfares and intersections. Several cities have explored the costs of these innovations, but have chosen not to adopt, or have tabled the decision. Perhaps the major difficulty facing the adoption of advanced snow control technology is the paucity of knowledge concerning the damage which occurs from snow and ice.

Emergency equipment--With the rapid expansion of the snowmobile industry since 1963, it would be only a short technological step to the design of larger snow vehicles for emergency use in cities. Vehicles could be constructed for use by police, fire, and utility departments. These machines would be particularly important in areas possessing minimum snow control capabilities.

Snowfests--To many Americans, the snowfest would probably be a rather unattractive alternative especially to a society that prides itself as nature's master. Snowfest's would amount to a declaration of a city holiday in response to a predetermined magnitude of snow. The amount required in the South would be small, whereas throughout the Snowbelt, those conditions with

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1/ For a discussion of some of the potential economic and social impacts of weather modification see: Derick Sewell et. al., Human Dimensions of Weather Modification, Chicago, University of Chicago Press, 1966.

which present programs could not handle would qualify. Severe ice storms and blizzards would suffice in most instances.

Throughout much of the Southeast a modified form of snowfest occurs with each major snowfall or ice storm. Schools are closed in some cases just in response to a storm forecast. Retail outlets and factories also shut down with relatively small accumulations. During winters with only one or two snows, the press often describes the chaos in positive or holiday like terminology. But even in the South there are a few who try and battle the elements.

The snowfest could work well, given societal acceptance and the provision of vehicles to cover true emergency situations. Snowbelt cities would undoubtedly recover faster from the five and ten year storms if a moratorium on travel was declared at the outset of the storm.1/ Based on past snow patterns, Northern cities would average only one snowfest per year. However, any given year could contain three or four such events. A similar pattern would hold true for the South.

Although it is unlikely that the snowfest adjustment will gain rapid acceptance, from the standpoint of social, economic, and aesthetic considerations it could be the most realistic alternative.

The Snowfest would be a natural adjustment in light of our aesthetic attraction to snow. Our unwillingness to wage an all out war on the snow hazard is likely a function of our positive association with it. The benefits of snow are as difficult to determine as the negative impact. How much is a White Christmas worth, or a drab winter landscape revitalized by a blanket of

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1/ It could be argued that the impact of several of the monumental storms of recent years in Chicago and New York could have been substantially lessened if such action had been taken. For much of the cleanup difficulties were related to the presense of abandoned vehicles on major arteries through the areas.

white. In those areas where prolonged snow-cover is common (Finland, Quebec, Northern New England) winter seems to assume a special meaning, with the pattern of life being distinct from other parts of the world.1/

The present range of adjustment in North America is fairly narrow with strategy generally emphasizing the use of large amounts of horsepower. In essense the past 50 years have witnessed the replacement of horses by machines combined, with a feeble attempt toward altering behavior. The possibilities for advancement are great if only the alternatives will be realistically evaluated.

1/ For an excellent discussion of the cultural meaning of winter see: W.R. Mead and H. Smeds, Winter in Finland, London, Hugh Evelyn, 1967.

TABLE 3-1

PER CAPITA EXPENDITURES FOR SNOW CONTROL AT SELECTED CITIES

| Area | City | Total Expenditures | Per Capita Expenditures 1968-1969 | Annual Snowfall (Managers Estimate) |
|---|---|---|---|---|
| Northeast | Greenwich, Conn. | $272,000 | $5.05 | 40" |
| | New Britain, Conn. | $340,000 | $4.13 | 40" |
| | Hamden, Conn. | $100,000 | $2.44 | 60" |
| | Auburn, Maine | $ 60,000 | $2.45 | 86" |
| | Lawrence, Mass. | $340,000 | $4.75 | 32" |
| | Newton, Mass. | $824,000 | $8.92 | 40" |
| | Quincy, Mass. | $330,000 | $2.29 | 50" |
| | Elizabeth, N.J. | $145,000 | $1.35 | 30" |
| | Trenton, N.J. | $ 5,500 | .05 | 23" |
| | Buffalo, N.Y. | $804,000 | $1.51 | 82" |
| | Syracuse, N.Y. | $508,000 | $2.35 | 104" |
| | Wilkes-Barre, Pa. | $ 64,000 | .85 | 53" |
| Southeast | Atlanta, Ga. | $100,000 | .21 | 2" |
| | Charlotte, N.C. | $ 20,000 | .10 | 11" |
| | Danville, Va. | $ 23,000 | .49 | 15" |
| | Norfolk, Va. | $ 50,000 | .18 | 13" |
| Midwest | Alton, Ill. | $ 16,000 | .37 | 18" |
| | Evanston, Ill. | $ 70,000 | .88 | 35" |
| | Waukegon, Ill. | $180,000 | $3.23 | 40" |
| | Ft. Wayne, Ind. | $200,000 | $1.24 | 32" |
| | Council Bluffs, Iowa | $ 63,000 | $1.12 | 33" |
| | Sioux City, Iowa | $267,000 | $3.00 | 35" |
| | Ann Arbor, Mich. | $130,000 | $1.92 | 32" |
| | Holland, Mich. | $600,000 | $24.22 | 100" |
| | Muskegon, Mich. | $145,000 | $3.10 | 120" |
| | St. Paul, Minn. | $950,000 | $3.03 | 42" |
| | Kansas City, Mo. | $320,000 | .67 | 23" |
| | Columbus, Ohio | $134,000 | .28 | 28" |
| | Youngstown, Ohio | $101,000 | .61 | 60" |
| | Cincinnati, Ohio | $573,000 | $1.14 | 21" |
| | Oshkosh, Wis. | $ 62,000 | $1.39 | 39" |
| West | Minot, N.D. | $ 60,000 | $1.96 | 35" |
| | Oklahoma City, Okla. | $ 39,000 | .12 | 9" |
| | Denver, Colo. | $314,000 | .64 | 55" |
| | Casper, Wyo. | $ 20,000 | .51 | 68" |
| | Lubbock, Texas | $ 14,000 | .11 | 8" |
| | Seattle, Wash. | $316,000 | .57 | 15" |

TABLE 3-2

MANAGERIAL OPINIONS REGARDING THE MOST SEVERE SNOW HAZARD CONDITIONS

| Area | Responses | Blizzards | Snow and Ice Storms | Snow and Cold Weather | Abandoned Cars |
|---|---|---|---|---|---|
| Northeast | 34 | 18(53%) | 9(26%) | 1(3%) | 6(18%) |
| Midwest | 55 | 40(75%) | 14(23%) | 0 | 1(2%) |
| Southeast | 10 | 5(5%) | 5(50%) | 0 | 0 |
| Plains | 8 | 4(50%) | 3(38%) | 0 | 1(12%) |
| Mountains | 4 | 4(100%) | 0 | 0 | 0 |
| Northwest | 3 | 2(67%) | 1(33%) | 0 | 0 |
| Total | 114 | 73(64%) | 32(28%) | 1(1%) | 8(7%) |

CHAPTER 4

# AN APPLICATION OF THE ADJUSTMENT MODEL

Clifford Russell

As we have noted earlier, of the several possible basic adjustments to urban snowfall, by far the most extensively adopted is that stressing maintenance of normal urban routine through the plowing or chemical treating of streets. This is also the adjustment for which it seems most reasonable to expect that, with present knowledge, meaningful cost and benefit estimates could be made. For these two reasons we have chosen it for an attempt at illustrative application of the adjustment model discussed in Chapter 2. In the following pages, we describe methods used and results obtained in this attempt. From these results, certain limited lessons may be drawn, but the quality of the cost and damage function estimates is not sufficiently high to support the weight of much generalization or of prescriptions for actual planning.

In Chapter 2, we showed that information relevant to decisions about adjustments to natural hazards included: The probability distribution of the natural events constituting the "hazard"; a description (in analytical, tabular, or other form) of the physical impact on human society of these events for given levels of adjustment; the damages associated with these physical impacts; and the costs of the adjustments.1/

1/ Strictly speaking, this catalog of necessary information applies only to one broad type of human adjustment; that aimed at softening the physical impact on society of unaltered natural events. Adjustments which alter the probability distributions of the natural events themselves (such as weather modification) involve us in essentially similar steps, but our basic aim there is the comparison of the alternative probability distributions.

At that time we also suggested that in studying the street-clearing adjustment to snowfall, a useful measure of adjustment, despite its inadequacies, would be a city's hourly snow removal capability in inches per hour.

Actual removal is not, of course, necessarily the strategy to be followed, and a more generally correct term might be snowfall "neutralization" capability, where "neutralization" implies the elimination of the disruptive effects of the snowfall, whether or not the snow were melted or pushed off the city's streets. Thus, for example, for very small storms, the application of abrasives alone might very well eliminate traffic disruption without any removal (except that occurring naturally because of temperature and traffic.) For storms of one to four inches, chemicals (usually sodium chloride with or without some calcium chloride) provide traction and produce removal by melting. But it is almost certainly not necessary to apply enough chemicals to melt, say, one inch of snow (of average density) per hour in order to neutralize that rate of fall, for the chemicals change the character of the snow on the ground.[1/] For large storms, it is generally considered necessary to plow the snow off the pavement, so that physical removal _is_ practiced. But the appropriate measure of "removal capability" to be associated with plowing is less obvious than it may appear.

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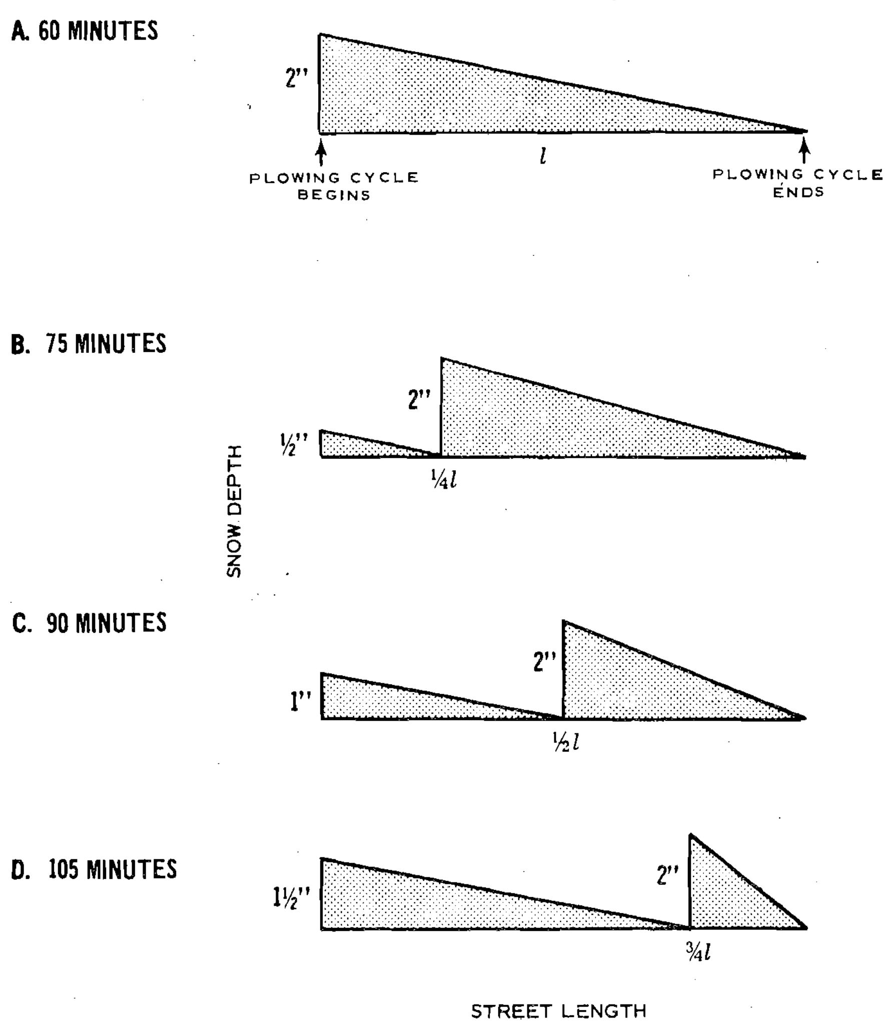
1/ Extensive laboratory tests of the _ice_-melting efficiencies of various chemical mixtures are reported in "Ice Melting Properties of Chloride Salt Mixtures", Highway Research Board Bulletin 220, National Academy of Sciences, National Research Council Pub. 679, Washington, D.C., 1959. These tests took account of the fact that an ice surface would be broken up by traffic after considerably less than 100 percent had actually melted. Indeed, our calculations indicate that 15-20 percent might suffice for ice neutralization. Even lower percentages might apply to snow accumulations.

Consider, for example, a city with a single, straight street so that we can easily draw a graph of snow depth along the street for varying removal rates. Assume that the rate of snowfall is 2" per hour. Then, if the street can be plowed once each hour, the average depth on the street at any time after the first hour will be 1 inch. Thus, graphically, the snow profile at 60, 75, 90, and 105 minutes would be:

Figure 4-1




A. **Average Depth** = $\frac{1}{2}\, 2\, l / l = 1''$

B. **Average Depth** = $\left[\frac{1}{2}\left(\frac{1}{2} \cdot \frac{1}{4}\, l\right) + \frac{1}{2}\left(2 + \frac{1}{2}\right)\frac{3}{4}\, l\right] / l$

C. & D. **Average Depth** = 1"

If, on the other hand, the street can only be plowed once every two hours, the average depth in the street increases to 2"; if every three hours, 3", etc. What are the removal capabilities represented by each of the alternative cycle times? One natural definition is the difference between the total depth of snow which would be on the street after one cycle in the absence of plowing and the average depth left by plowing, divided by the hours required to perform the cycle. Under this definition we obtain:

| | Total toll | Ave. depth after plowing | Difference | Cycle time | "Removal" capacity |
|---|---|---|---|---|---|
| 1 hour cycle | 2" | 1" | 1" | 1 hour | 1"/hour |
| 2 hour cycle | 4" | 2" | 2" | 2 hours | 1"/hour |
| 3 hour cycle | 6" | 3" | 3" | 3 hours | 1"/hour |

Clearly something is amiss, for if the city's plows can only be operated at a single speed, then it must take 3 times as much equipment to plow every hour as every 3 hours.

But if we return to the idea of neutralization, it is possible to develop a measure of plowing removal capability which makes sense. First, we must pick an average depth which causes effectively zero damages. Then, for a given street system, the cycle time will determine the largest (continuous) rate of fall which can be neutralized, in the sense of being kept at the zero-damage depth on the average. Thus, for a zero-damage depth of one half inch, a cycle time of one hour defines a removal capability of 1 inch per hour. A cycle time of 2 hours implies that removal capability is ½" per hour, etc.

The above discussion suggests that the actual relation between snow-fall, removal or neutralization capability, accumulation on streets and losses suffered by society must be quite complex. Indeed, one should really discuss several specific "removal" adjustments (abrasives, chemical application and plowing) separately, taking account, however, of how they may be combined, and using some variable such as "effective snow depth" as the basic measure of physical impact (where effective snow depth would take into account the presence or absence of abrasives and chemicals and would reflect a judgment about the level of average snow accumulation producing zero damages.) In our illustrative application we adopt the simple view that "removal capability" really involves removal and that losses are sensitive to accumulation only (with no allowance for the presence of chemicals or abrasives, except as chemicals produce removal). As we shall see below, this approach simplifies the estimation of damages, but makes it rather difficult to estimate meaningful cost functions for level of adjustment.

## The Basic Data

In this chapter, then, we describe the estimation of damages and costs related to snow removal capability. Originally we chose six cities of roughly 100,000 - 200,000 population as a sample for which to obtain weather data and in which to conduct interviews concerning municipal removal capability and related costs, and private damages and adjustments.[1/] These cities were: Nashville, Tennessee; Evansville, Indiana; Canton, Ohio; Rockford, Illinois; Utica, New York; and Worcester, Massachusetts. They were chosen with the idea of including two cities

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1/ In Chapter 5 we discuss the results of the interviews with retail and manufacturing establishments in the sample cities.

with light snowfall (Nashville, Evansville); two with medium (Canton, Rockford) and two with heavy snow (Worcester, Utica). Unfortunately, it proved impossible to obtain the required hourly precipitation data for Utica, and our sample was reduced to five cities after interviews had been conducted. Table 4-1 summarizes some of the pertinent data for these five cities.

Unfortunately, for none of these cities were hourly snowfall data available for any significant period. Thus, it was necessary to convert hourly data on precipitation in equivalent water inches to hourly snowfalls using information on total snowfall for each day. This procedure, if performed in the simplest way (i.e., dividing total daily snowfall by total daily water equivalent inches of precipitation and using this factor to convert the hourly readings), has a built-in bias in the direction of underestimating individual hourly falls. This is because every hour's precipitation need not be snow, but unless additional information is available, each hourly figure will be converted to snowfall in such a way as to reproduce the recorded daily snowfall. Thus, the depth of some actual hourly falls may be underestimated by the spreading of a given daily total over more hours.1/ In an attempt to correct for this bias, our conversion program took into account the variation of snow density with temperature.2/ Unfortunately this technique did not always reproduce the daily recorded falls,

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1/ New weather records include hourly indications of the form of precipitation.

2/ The program was written by Mr. Joe Sage, a student in the Graduate School of Geography, Clark University, Worcester, Massachusetts, as part of his projected Ph.D. thesis work on synthetic snowfall generation.

Table 4-1

Selected Characteristics of Study Sites

| | Population (1960) | Approximate street mileage subject to snow removal | City Area (1960) sq. miles | Long term mean annual snowfall 1/ for no. of years in parentheses) | Mean annual snowfall over period for which hourly precip.data avail. (period in parentheses) 1, 2 |
|---|---|---|---|---|---|
| Canton | 113,630 | 400 | 14.3 | 38.7"(70) | 49.6"(1951-68) |
| Evansville | 141,543 | 480 | 32.0 | 14.4"(70) | 13.6"(1951-69) |
| Nashville | 170,874 | 270 | 29.0 | 9.0"(70) | 12.4"(1951-69) |
| Rockford | 126,706 | 440 | 26.0 | 31.7"(54) | 36.6"(1959-69) |
| Worcester | 186,590 | 353 | 37.0 | 60.0"(59) | 71.5"(1957-69) |

1/ Calender year averages.

2/ The hourly precipitation data are available through the present, but we stopped with 1969 because calculations started early in 1970.

a fact that was discovered too late for correction. This resulted in the elimination of one city, Canton, Ohio, where the annual snowfalls generated were much smaller than those recorded during the period.3/ The principal reason for this discrepancy was apparently the frequency with which snowfalls in Canton occurred while the temperature was very close to freezing. The characteristics of the recorded and calculated snowfalls for the four remaining cities are shown in Table 4-2.

3/ The Rockford snowfalls were also smaller but fell barely outside a 95 percent confidence interval around the recorded means and so seemed representative enough to use in the illustrative damage calculations.

Table 4-2

Selected Snowfall Characteristics of Study Sites

| | Recorded average annual snowfall (for period indicated) | Calculated standard deviation of recorded snowfall totals | Generated average annual snowfalls for period |
|---|---|---|---|
| Evansville | 13.6"(1951-69) | 8.1" | 9.1" |
| Nashville | 12.4"(1951-69) | 10.3" | 9.1" |
| Rockford | 36.6"(1959-69) | 11.3" | 22.2" |
| Worcester | 71.5"(1957-69) | 24.4" | 67.3" |

Note: An additional problem with the snowfall conversion was that we limited ourselves to the months November through April, while in some of the cities, significant snowfalls occasionally occur in October and even in May.

The Damage Model

Losses result from the accumulation of snow on city streets for three basic reasons: some people are prevented from making necessary or desired trips--especially those for work or shopping; those trips that are made involve lower average speeds than they would under normal conditions, with consequent increases in costs of vehicle operation and losses of time by the travellers; all travellers face increased risk of accident because of slippery conditions.1/ In addition to the effects on

1/ Some brief qualifications are in order at this point, although several more will be noted in the text. First, if normal average speeds are very high--say about 45 or 50 mph--their reduction may produce operating cost savings because the auto engine's most efficient operating speed is around 40 mph. Second, there is some evidence that decreased speeds and increased driver care may actually lead to reduced traffic accident risk during heavy snowfalls. From our point of view, it is conservative to assume that accident risk increases with accumulation.

private individuals, snow accumulation will hinder commercial and industrial traffic in a similar way. The actual estimation of all these effects would be a considerable research task in itself but fortunately for us it is a task which has been attempted previously and we were able to make use of information contained in such a study published by the American Public Works Association.1/ Because the study was based on the storm as the unit of time and because the results were presented graphically and not in functional form, the adaptation of the results to our study involved considerable effort.2/

The computational damage model is shown schematically in Figure 4-2. The basic data are of course, the hourly snowfalls already discussed. From these and the assumed value of removal capability, P, are calculated hourly snow accumulations. For each city, annual data on auto registration, employment, average wages and urban radius are introduced. From the APWA study we took values of average trip lengths for workers and non-workers and average number of occupants per car. (We let these remain constant for all cities and years, though it would be preferable to have data for each city and year.) We assumed that wages are a constant fraction of total value added in each city, and that some fraction, denoted by p, of value added "lost" because of worker absences, is made up at a later time

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1/ See Snow Removal and Ice Control in Urban Areas, AWPA Research Foundation, Project No. 114, Vol. I, Chapter 7, "Economics of Ice and Snow Removal in Urban Areas" (Chicago, August, 1965).

2/ This task was made more difficult by the rather sketchy explanation accompanying the graphs in the study report.

under conditions of less than full employment.1/ (We let p = .1 and .9 in order to demonstrate the sensitivity of results to this effect.) We also assumed that for each city, commercial traffic volume could be estimated from private traffic volume using the relation between commercial and private vehicle registrations.2/

From the AWPA study we developed in analytical form the functions shown in Figure 4-2 and the Appendix to this chapter. For most of these it was sufficient simply to estimate a functional form which matched the graphs of the study. One of the key elements in the model, however, involved complete translation of one approach and time scale into another. This was the relation between accumulated snowfall on streets and the average speed at which auto trips could be made in the urban area. In the APWA study, this relation was presented in a long series of graphs showing, for storms of differing lengths and hourly rates of snowfall, the fraction of normal trip speed attained at any time during the course of the storm.3/ For each storm type, several relations were shown which

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1/ See C. S. Russell, D. G. Arey and R. W. Kates, Drought and Water Supply: The Implications of the Massachusetts Experience for Municipal Planning (Baltimore: Johns Hopkins Press,November 1970), for a discussion of the correct measurement of "lost" production, the correction for transferral or deferral, and the role of accounting stance. We adopt here a local stance; this generally tends to give the largest loss estimates.

2/ Vehicle registrations were obtained for 4 cities during the interviews. For one it was necessary to go to a commercial firm which maintained the required data for sale to advertisers and other business interests.

3/ This relation was also differentiated by temperature, one set of graphs being given temperatures above and one for temperatures below 25°F.

SCHEMATIC DIAGRAM OF SNOW DAMAGE MODEL

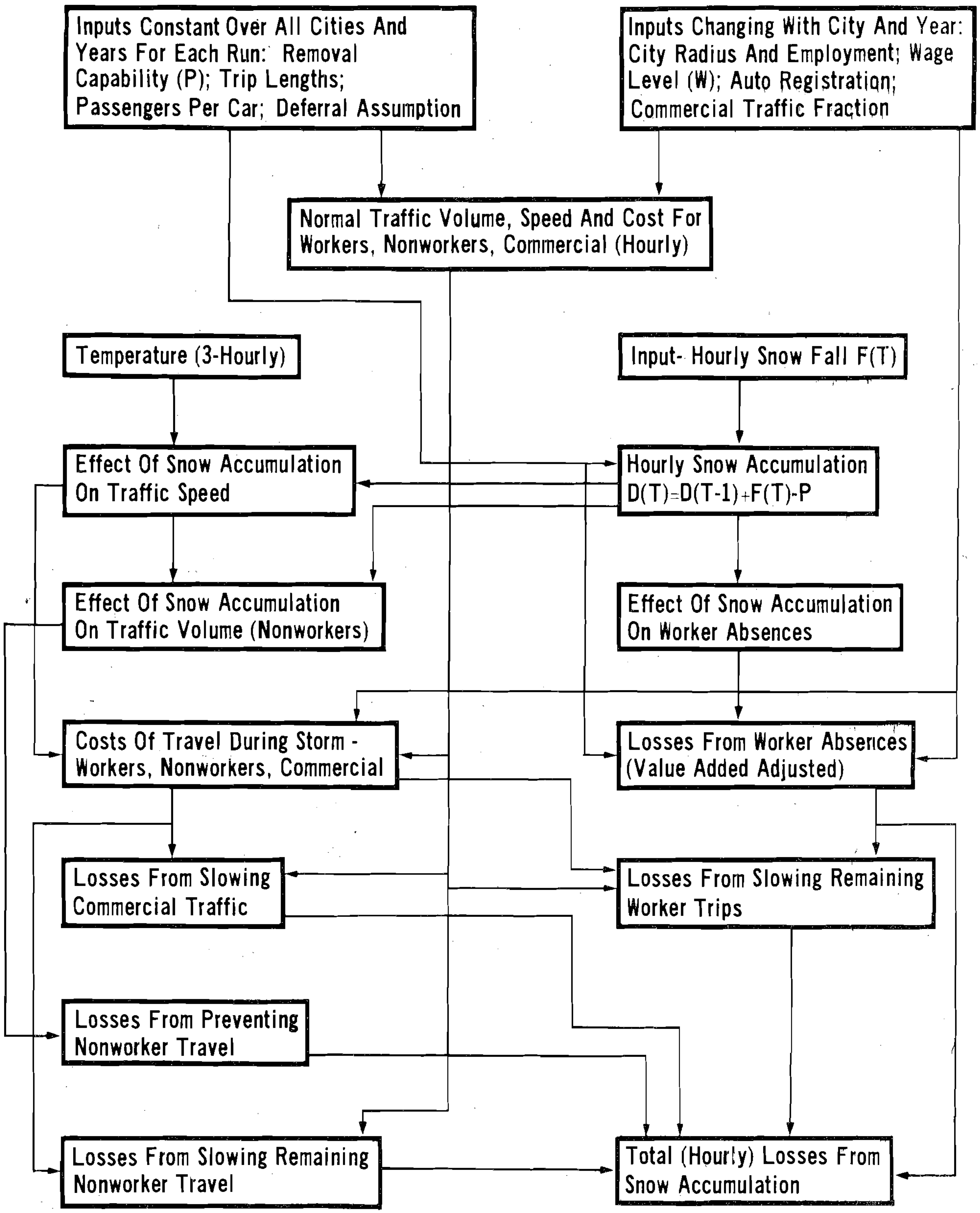



Figure 4-2

presumably reflected differing rates of removal. (An example of one of these graphs is included as Figure 4-3.) Unfortunately, the graphs were not labelled to allow the reader to tell what removal capabilities were assumed for each line. In this situation, we assumed that in each figure, the curve showing the longest and most severe disruption was based on zero removal effort by the municipality and reflected simply the natural removal occasioned by sun, air temperature and traffic. From these zero-removal curves, given the assumed rate of snowfall, we could estimate the fraction of normal speed associated with a number of depths of accumulation. 1/ From these observations, we estimated, by simple regression techniques, the relation as:

Fraction of normal trip speed (SF) = $e^{-B_T D}$,

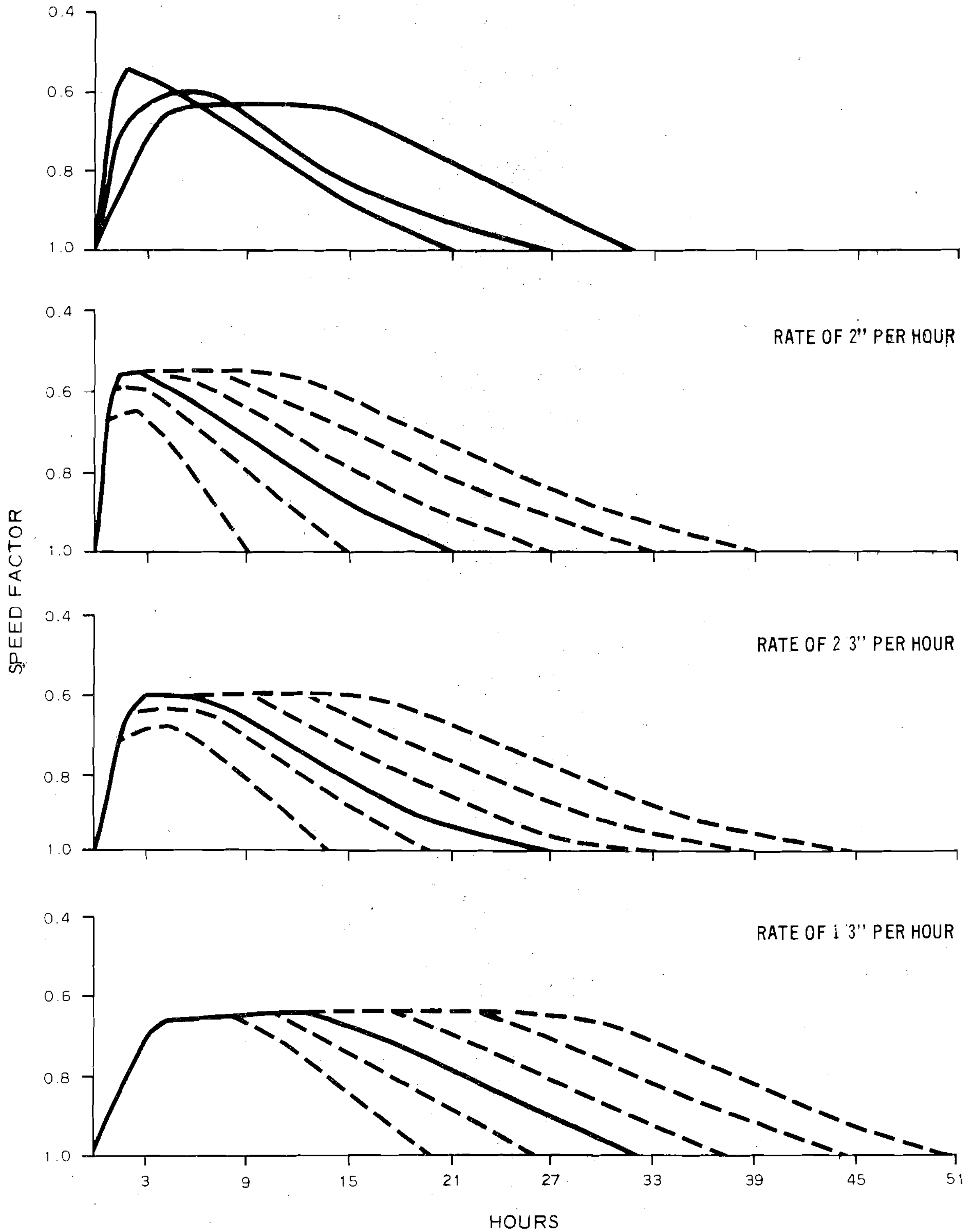
where D is accumulated snow depth; $B_T$ is the constant estimated from the graphs; and the subscript, T, indicates that the constant is different for temperatures above and below 25°F.

The results, in terms of average annual damages and the standard deviation of annual damages, of combining the snowfall records, city data and damage estimation model are presented in Table 4-3. In order to remove the effect of city-size, and show more clearly the impact of different snow environments, we show in Table 4-4 the average annual losses *per capita* along with the average annual snowfall calculated from the hourly records generated for use in the damage model. 2/ From the two tables we

1/ We had observations for each temperature range, with depths of from .5 to 4.0 inches and corresponding reductions in trip speeds from .95 to .50 of normal.

2/ We use the 1960 populations to deflate the average annual figures from Table 4-3 rather than using interpolated and extrapolated population figures to deflate each year individually.

## SAMPLE STORM SPEED FACTOR CURVES FOR 4 INCH SNOW ABOVE 25° F




*Source: American Public Work Association, 1965, p.87*

**FIGURE 4-3**

can see that the average annual damages, particularly under a low assumed ability to defer lost production and sales, are very high for low values of P, the removal capability. Thus for Nashville, with an average of only 9.1 inches per year, average annual damages per capita could be as high as $13.72 if P = .05"/hr., or $7.47 if P = .10"/hr. Worcester, with roughly 7.5 times as much snow on the average as Nashville, had 15 to 20 times larger average annual per capita damages. These losses fall rapidly with increasing P, however, with the 20-fold increase from P = .05 to 1.0, reducing them by a factor of roughly 200. (This is true for both values of p.) At all assumed levels of P and for both values of p, the standard deviations of losses are generally at least as large as the means themselves, indicating that great variability can be expected from year to year in losses suffered, whatever value of P is chosen. Indeed, the combination of large average losses and great variability suggest that a damage function taking account only of expected values may not be adequate for decision-making. It may be necessary to introduce explicitly some measure of variability, such as a fraction of the standard deviation, in an attempt to capture what it is reasonable to assume is the community's aversion to the risk of very large losses in particular years.1/

The actual choice of the method of inclusion of a variability measure, and more important the choice of the relative weights for

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1/ See, for example, Maass, et al, The Design of Water Resource Systems (Cambridge: Harvard University Press, 1966), pp. 129-152.

Table 4-3

Average Annual Losses from Snowfalls Assuming Various Removal Capabilities

| | | Removal Capability (P) in/hr. | | | | |
|---|---|---|---|---|---|---|
| | | .05 | .10 | .25 | .50 | 1.0 |
| **Low Production/Sales Deferral: p = .10** | | | | | | |
| Evansville | (mean) | $1,902,500 | $851,300 | $229,500 | $61,100 | $10,100 |
| | (S.D.) | 3,203,000 | 1,530,400 | 464,700 | 151,200 | 31,400 |
| Nashville | (mean) | $2,344,600 | $1,277,000 | $369,200 | $83,100 | $13,800 |
| | (S.D.) | 5,312,700 | 3,396,600 | 1,062,300 | 238,000 | 43,500 |
| Rockford | (mean) | $3,204,100 | $1,231,200 | $246,900 | $36,000 | $800 |
| | (S.D.) | 2,959,200 | 1,264,300 | 314,000 | 51,100 | 1,100 |
| Worcester | (mean) | $48,369,000 | $23,930,000 | $6,254,000 | $1,512,100 | $208,300 |
| | (S.D.) | 39,018,000 | 22,748,000 | 6,160,000 | 1,622,300 | 283,400 |
| **High Production/Sales Deferral: p = .90** | | | | | | |
| Evansville | (mean) | $324,000 | $144,800 | $38,900 | $10,800 | $2,200 |
| | (S.D.) | 537,500 | 256,200 | 76,400 | 25,600 | 6,400 |
| Nashville | (mean) | $496,300 | $195,200 | $45,200 | $10,100 | $1,800 |
| | (S.D.) | 1,307,300 | 479,600 | 98,900 | 19,300 | 4,300 |
| Rockford | (mean) | $553,200 | $199,400 | $43,900 | $7,700 | $300 |
| | (S.D.) | 379,000 | 156,300 | 41,500 | 8,400 | 400 |
| Worcester | (mean) | $8,357,000 | $3,795,000 | $942,000 | $232,000 | $32,300 |
| | (S.D.) | 9,494,000 | 4,299,000 | 1,004,000 | 246,800 | 39,400 |

Table 4-4

Average Annual Per Capita Losses from Snowfalls for Various Removal Capabilities

| | Removal Capability (P)in/hr | | | | |
|---|---|---|---|---|---|
| | .05 | .10 | .25 | .50 | 1.0 |
| Low Production/Sales Deferral p = .10 | | | | | |
| Evansville (9.1")1/ | 13.44 | 6.02 | 1.62 | .43 | .07 |
| Nashville (9.1") | 13.72 | 7.47 | 2.16 | .49 | .08 |
| Rockford (22.2") | 25.29 | 9.72 | 1.95 | .28 | .01 |
| Worcester (67.3") | 259.21 | 128.24 | 33.52 | 8.10 | 1.12 |
| High Production/Sales Deferral p = .90 | | | | | |
| Evansville (9.1") | 2.29 | 1.02 | .27 | .08 | .02 |
| Nashville (9.1") | 2.90 | 1.14 | .26 | .06 | .01 |
| Rockford (22.2") | 4.37 | 1.57 | .35 | .06 | <.01 |
| Worcester (67.3") | 44.78 | 20.34 | 5.05 | 1.24 | .17 |

1/ Generated average annual snowfalls for the period over which damages calculated. Based on conversion of hourly records of precipitation in water equivalent inches.

average losses and variability of the annual losses, would not be easy. But the effect of one such choice on the "optimal" level of adjustment is illustrated below by the construction of damage functions of the form:1/

D(A) = expected annual losses + ½ standard deviation of annual losses

The third major observation about the tables of average annual losses is that the change from 10 to 90 percent deferral of "lost" production and sales reduces losses by a factor of roughly 6 to 8. This effect results from the fact that "losses" (of production and sales) related to worker absences due to snow accumulation, while by far the largest part of total losses when p = .10, are not the only component of total losses. Losses resulting from slower trip speeds are not affected by the change in the deferral assumption, and hence the reduction in total losses with an increase in p is less than proportional.

It is worth noting that the losses resulting from S inches of snowfall in a single year will vary greatly for given P, depending on whether that snow falls over many hours at low hourly rates or over a few hours at high rates. Hourly losses are non linear in the hourly accumulation, and, in addition, for given P, higher hourly rates of fall will produce more hours during which some snow is on the streets. Similarly, for larger P, losses will tend to be reduced more rapidly where the same total snow falls at lower hourly rates over more hours. The data in Table 4-3 do not suggest that there is a tendency for cities

1/ Under fairly general conditions, this form of damage function will result in a higher level of adjustment being optimal than will the expected losses alone.

with higher average annual snowfall to suffer from proportionally more large hourly rates of fall. (We return to this point again below in discussing the costs of removal capability.)

The Costs of Adjustment

Damages are only half the picture, of course, for we cannot choose a level of adjustment without knowing how much our decision will cost us as well as how much it will save us in damages avoided. In the time frame of our illustration, the relevant costs are those involved in maintaining, for a year, a certain level of snow removal or neutralization capability, whether or not that capability is exercised in any particular storm. As we discussed in Chapter 2, these costs are primarily related to equipment inventories, long term chemical supply contracts and employment of key men who cannot be hired and laid off for each storm. In addition, a complete accounting would reflect the external costs or damages caused by the application of chemicals as part of the removal process.1/ These costs include: the damage to motor vehicles from corrosion, most obviously the destruction of mufflers, tail pipes and certain vulnerable body sections,2/ the contamination of soil along streets with consequent damage to vegetation;1/ the pollution of waterways with the heavily mineralized runoff

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1/ These costs are external to the decision making unit, the city government. Whether or not costs external to the city are considered will depend on the accounting stance chosen by (or forced on) the decision makers.

2/ The American Public Works Association is publishing this month (September 1970) a study report on motor vehicle corrosion resulting from chemical treatment of streets for snow removal.

3/ On the relation between street salting and roadside soil chemical composition, see F. E. Hutchinson and B. E. Olson, "The Relationship of Road Salt Applications to Sodium and Chloride Ion Levels in the Soil Bordering Major Highways," Highway Research Record, 193 (1967), pp. 1-7.

from treated streets; 2/ and possibly the disruption of sewage treatment facilities from this same source.3/ These external costs are, however, difficult to measure, particularly when they involve water pollution and damage to vegetation, and there is presently insufficient published information, even on the relatively straightforward matter of vehicle damage, to permit us to include external costs in our adjustment cost function. This omission will have the effect of raising the "optimal" level of adjustment (removal capability) implied by our damage and cost functions.

Even the standard "internal" costs associated with maintaining particular levels of removal capability, however, present certain conceptual measurement difficulties. First, the distinction between the long and short runs, between those costs which must be incurred to maintain a given removal capability and those associated with cleaning up after particular storms, may not be clear. For example, how does one treat a

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1/ Results of research into the extent to which runoff from treated highways affects water quality are reported by F. E. Hutchinson in "Effect of Highway Salting on the Concentration of Sodium and Chloride in Rivers," Research in the Life Sciences, Winter 1968, pp. 12-14. The reported project turned up no evidence that sodium and chloride concentrations were related to rural highway salting. It seems reasonable to expect, however, that salting in an urban area could produce large sodium and chloride "shocks" to receiving waters because of the much larger treated areas involved.

2/ If the municipality runs the sewage treatment plant, then this is not strictly an external cost, since the city government would in theory be expected to internalize the costs that one of its activities imposes on another. This kind of comprehensive view may almost never be found in practice, however, especially since street clearing and treatment plant operation may fall under different departmental jurisdictions.

We asked in our interviews about our respondents' knowledge of treatment-plant problems caused by salting. None of the interviewed managers indicated any such knowledge, but two stressed problems of storm-sewer clogging caused by abrasives.

city which relies on an informal agreement with local contractors to obtain the equipment needed to deal with large storms? No long run costs are apparently incurred by the city. Do the contractors, because of the agreement, own more equipment than they otherwise would? Does the city pay a higher rental fee than it would with a contract? Similar but perhaps even tougher questions arise in connection with short run mobilization decisions. In order to exercise a planned removal capability, the city will have to begin salting and plowing early in the storm, before traffic snarls prevent even city trucks from moving. This will frequently imply pre-storm mobilization, i.e., mobilization based on forecasts of an approaching storm. Thus the city, in evaluating the costs of maintaining alternative removal capabilities, really must consider some short run costs of exercising those capabilities in time for them to be meaningful. (Notice also that since forecasts are not always correct, an additional cost element will be that of mobilization which were not, in fact, necessary but which had to be undertaken based on forecast information and the assessment of forecast reliability.)

Another conceptual difficulty in cost measurement is the allocation of costs of equipment used in more than one role by the city (for example garbage trucks to which plows are attached and general-purpose trucks on which chemical spreaders are mounted). Any allocation of average costs, for example on the basis of time or miles in alternative service roles, is essentially arbitrary. But the information needed for correct decisions, the marginal equipment cost of opting for a higher removal capability, will almost certainly be difficult or impossible to discover and one or another arbitrary allocation will have to be used.

A final conceptual difficulty arises from the complexity of the relations between the major alternative methods of neutralizing snowfalls. Changing the removal capability from .9 to 1.0 inches per hour probably does not involve simply owning more equipment to do exactly the same things, but rather may involve a change in the mix of methods. (For example, relatively greater reliance on plowing and less on salting, earlier mobilization and a change in the composition of chemicals applied.)

Despite these difficulties, we originally hoped to gather sufficient data on costs and associated removal capabilities, both in our interviews in the sample cities and from the public works literature, to generate a function which would reflect those costs affected by relatively long term decisions about the appropriate level of adjustment to the snow hazard.1/ But in these efforts we ran into further, practical difficulties. First, neither in the interviews nor in the literature did public works officials normally discuss cost in relation to any desired removal or neutralization capability. The most widely used terms of reference were total annual costs per inch of total annual snowfall per mile of city streets "maintained" (i.e. streets subject to plowing and/or chemical application). We ran across only two major exceptions to this rule and one indication that the usefulness for planning of thinking in terms of inches-per-hour removal

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1/ To this end we devoted an extensive section of our questionnaire to attempting to obtain information on equipment inventories and costs, average lives, buying cycles and extent of alternative uses. This effort was not successful. We also undertook a rather complete literature search, some of the fruits of which will appear below.

or neutralization capability is recognized.1/ The first exception was an article on Newton, Massachusetts, in The American City, which contained a description of Newton's "design storm" (i.e., that storm with which their removal system was designed to deal effectively) as 12 to 16 inches accumulation, with a rate of fall of 1.5 inches per hour.2/ The other exception to the absence of references to hourly removal capability came, perhaps not surprisingly, in articles about heated pavements as a method of keeping key traffic spots open.3/ (We say "not surprisingly" because in the melting of snow by heating pavement areas there are none of the ambiguities concerning the meaning of "removal" which we have discussed both in this chapter and in Chapter 2.) Both articles agreed in recommending that systems should be designed with the capability of melting one inch per hour, even though highest recorded rates of fall might be 3 or 4 inches. The articles also agree reasonably well (after allowing for instruction cost inflation) on the capital costs (material, equipment and installation) of heated pavement areas: about $4.00 per square foot. Operating costs depend, of course, on the price of electricity (or steam) and on the number of hours of operation per year. But by assuming various simple relations between average

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1/ The latter indication is a recent article by Paul D. Tomlingson, "Organizing for Winter Maintenance," in Public Works, Vol. 101, No. 8, August 1970, pp. 52-54, in which the explicit choice of a design hourly snowfall is advocated.

2/ "Newton, Mass., Measures its Snow-fighting Strength," American City, December, 1960, pp. 106-107.

3/ An early article by James B. Fullman, "Snow Melting Systems," The American City, Vol. 57, No. 6, June 1952, pp. 92-94, discussed systems using steam in pipes. More recently, J. M. Pittman, in "Experience with Electrically Heated Pavement," Public Works, August 1969, pp. 97-100, deals with implanting conducting cables in pavement.

annual snowfall and average total hours of snow, we can calculate illustrative operating costs for a given energy price. If, for example, we assume a capital recovery factor of .10 (which would correspond to a life of 20 years with a discount rate of 8 percent), the annual capital costs for a mile of heated pavement 24 feet wide would be $50,800. The heat required to melt one inch per hour of snow with a density .1 times that of water is 72 BTU per square foot. This is equivalent to 21.1 watt hours of electricity. Allowing for heat losses into the surrounding soil, about 100 BTU per hour or 29.3 watt hours are required per square foot. This implies a total energy input of 3720 kwh per mile per hour.1/ At $.009 per kwh, hourly operating costs would be $33.40 per mile. In Table 4-5, we show the total annual costs (capital plus operating) and annual costs per inch for one mile of heated pavement under several different assumptions about total annual snowfall and hours of operation. These figures represent extreme upper limits on the costs per inch per mile of removal capability. (In normal application, of course, heated pavements are only used for small areas, critical to traffic flow, such as sloping approaches to bridges and thruways.)

But to return to our primary interest, the estimation of a cost function for standard removal methods related to removal capability in inches per hour, the rest of the rather large amount of literature on snow did not mention "design falls," even though it did provide us with considerable information about reasonable ranges for average annual "snow-

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1/ We assume that the only control is an on-off switch so that energy input cannot be varied to meet different rates of fall. This seems to be the case in the installation described by Pittman, *ibid*.

fighting" costs per inch per mile.1/ In addition, a number of research reports are available discussing the use of sodium and/or calcium chloride to attack snow and ice.2/ These generally give very careful accounts of costs incurred using various chemical mixtures, but none discuss the entire snow-fighting program in the test area, or the specific place of chemicals in that program. There is no way of relating the cost and weight information

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1/ In this literature, "snow removal" frequently means actual physical removal, as from downtown streets, where human or mechanical loaders and dump trucks are used. "Snow-fighting" is often used to refer to the plowing and chemical treatment of streets. There is no ready guide to this literature, and a complete listing would be tedious. A few of the more interesting articles of recent years, however, include:

--W. J. Rheinfrank, "Transit Mix Trucks Serve on Snow Plowing Teams," Public Works, September 1969;

--F. Worth Landers, "The Winter That Was!", Public Works, August 1969, pp. 82-84;

--R. R. Fleming, "More Plows and Better Plans," The American City, November 1968, pp. 69-72 and 132, 134. (This is a report of a survey by the journal of cities all over the U.S. It was also conducted and reported on in 1964 and 1961.)

2/ See, for example:

--New York State Thruway Authority, "Chemical Mixture Test Program," 1958-1960;

--Highway Research Board, "Ice-Melting Properties of Chloride Salt Mixtures," Bulletin 220, National Academy of Sciences, National Research Council (publication 679), Washington, D.C. 1959;

--Lawrence Miller, "Calcium Chloride-Salt Snow and Ice Control: Winter 1961-62," Research Report 2, Connecticut State Highway Department. (No date or place of publication, but available from Calcium Chloride Institute, Washington, D.C.)

--E. L. Miller, "Models for Predicting Snow Removal Costs and Chemical Usage," a paper presented at the Symposium on Snow Removal and Ice Control Research, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, N.H., April 1970.

Table 4-5

Annual Costs of Snow Removal Using Electrically Heated Pavements: 1 inch per Hour Removal Capability

| Average annual inches of snowfall | Average annual hours of operation | Average annual operating costs (one mile) | Annual capital cost (one mile) | Average annual cost per mile | Average annual costs per inch, per mile |
|---|---|---|---|---|---|
| 10 | 20 | $ 670 | $50,800 | $51,470 | $5,150 |
| | 30 | 1,000 | 50,800 | 51,800 | 5,180 |
| | 40 | 1,340 | 50,800 | 52,140 | 5,210 |
| 30 | 60 | 2,000 | 50,800 | 52,800 | 1,760 |
| | 90 | 3,010 | 50,800 | 53,810 | 1,790 |
| | 120 | 4,010 | 50,800 | 54,810 | 1,830 |
| 50 | 100 | 3,340 | 50,800 | 54,140 | 1,080 |
| | 150 | 5,010 | 50,800 | 55,810 | 1,120 |
| | 200 | 6,680 | 50,800 | 57,480 | 1,150 |
| 70 | 140 | 4,680 | 50,800 | 55,480 | 793 |
| | 210 | 7,010 | 50,800 | 57,810 | 825 |
| | 280 | 9,350 | 50,800 | 60,150 | 860 |
| 100 | 200 | 6,680 | 50,800 | 57,480 | 575 |
| | 300 | 10,020 | 50,800 | 60,820 | 608 |
| | 400 | 13,360 | 50,800 | 64,160 | 642 |

to rates of snowfall, proportion of snow melted, or maximum accumulation considered safe on roads involved; in short, there appears to be no way of using these data in estimating costs of specified levels of adjustment.

In this situation, it seemed necessary to try to make use of such information as we had for our sample cities. This included: detailed snowfall data (the hourly records discussed above plus summaries of monthly and annual totals, largest 24 storms on record, etc.); associated climatic data, such as normal daily maximum temperature for each month; and cost information of varying quality (none for Evansville). To attempt to obtain indirect estimates of intended removal capabilities, we first calculated, from our hourly snowfall records, the 90 percent hourly rate (the rate larger than 90 percent of all hourly falls). But this figure, to our surprise, did not differ between cities with very different mean annual falls. Thus, for both Nashville (mean = 9.1"/yr.) and Worcester (mean = 67.3"/yr.) the 90 percent snowfall over our record was 1.0 inch/hour.1/ It seems that in Worcester it simply snows many more hours per year without snowing harder, on the average, during individual hours.2/ On the other hand, the largest 24-hour storms do differ significantly between Nashville and Worcester (although not among Evansville, Canton, Rockford and Nashville), which suggests that heavy hourly falls may occur in series more frequently in areas of larger annual total snowfall. We

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1/ The 95 percent fall was actually larger for Nashville.

2/ See the discussion on page 18, above. There we found no evidence, from the pattern of damage sensitivity to assumed removal capability, that the cities with high average snowfalls had proportionally more hours with very heavy falls.

chose to use the record 24-hour snowfall, divided by 24, as a partial surrogate for desired removal capability. The other determinant of this capability, we took to be normal daily maximum temperatures for January, to reflect the likely residence time of snowfalls on city streets. We further assumed that these two are traded off against each other in determining removal capability, so that a city with higher temperatures can accept higher hourly snowfalls while maintaining the same removal capability.1/ Plotting our five sample cities as points on a graph of largest 24-hour snowfall (divided by 24) against normal daily maximum January temperature, we obtain Figure 4-4. We note that the cities cluster according to mean annual snowfall.

Three more assumptions were necessary to match costs to a removal capability. First, we assumed that tradeoffs of temperature against rate of fall occur along straight lines. Second, we chose to draw these lines as rays from an origin at which the rate of fall variable was zero, and the temperature variable, -10°F.2/ (This temperature was chosen because it was significantly below normal daily maximum January temperatures for the contiguous United States.) These rays, drawn from the origin to each of the clusters representing approximately equal annual average snowfalls,

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1/ It is reasonable to expect that air temperatures are considered in choosing removal capabilities. The method we outline here, however, assumes that all cities choose an adjustment level on the basis of physical records alone without considering costs or damages. This may or may not be correct, but it should be subject to empirical test. The best we can do is to compare later our results for optimal removal capability with the levels implied by this assumption and the weather records.

2/ Our results would not be sensitive to changes in this temperature origin over a fairly wide range.

are shown in Figure 4-4. Finally, to associate a standard removal capability with each ray, we chose the intersection of the ray with the vertical line representing 32°F. This gives us removal capabilities of .33 in./hr/ (Nashville-Evansville), .45 in./hr. (Rockford-Canton) and 1.00 in./hr. (Worcester). Combining this information with estimates of average annual snow-fighting costs per inch per mile from our interviews, we obtain the lower three points along the curve in Figure 4-5.1/ A curve through these points may be approximated by the expression:

$$C = 35\ P^{1.43}$$

where C is annual cost per inch per mile and P is chosen removal capability.

As tortuous as the above method and reasoning are, it is interesting to note that independently developed data for Newton, Massachusetts, place that city's costs per inch per mile and chosen removal capability very close to the curve in Figure 4-5.2/ Thus, although the results quoted below are primarily illustrative, the cost function on which they are based

---

1/ Because of the problems cited above, of separating long run and short run costs affected by a decision to maintain a particular removal capability, the use of average (total) annual costs does not seem particularly dangerous. It may result in some over-estimation of the relevant costs for any chosen removal level, and thus in a tendency for the "optimal" removal levels found below to be too low.

2/ We have already mentioned that Newton was the only city for which we found a chosen removal capability in the literature. The costs per inch per mile were calculated as the basis of information supplied by Newton officials in response to our mail questionnaire.

## DETERMINATION OF REMOVAL CAPABILITY BASED ON PHYSICAL RECORDS

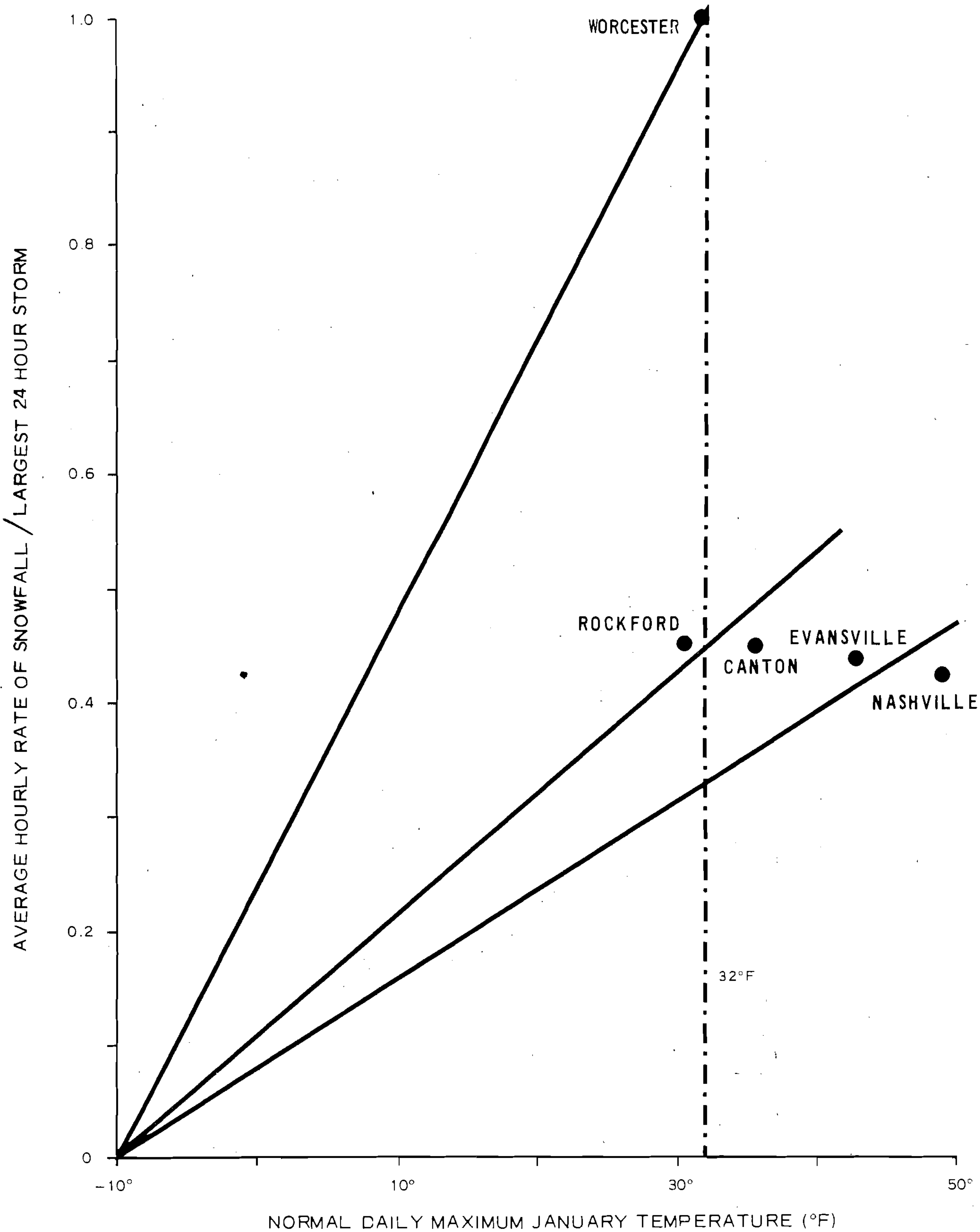


FIGURE 4-4

appears to accord with such limited empirical information as we have found.1/

Optimal Adjustment Levels: Combining Costs and Expected Losses

Now we are in a position to combine our estimates of costs and losses as functions of removal capability in order to find "optimal" levels of that capability for our sample cities. Thus, from Table 4-3, containing information on average annual losses to Evansville, Nashville, Rockford and Worcester, we may construct damage functions like the one pictured for Nashville in Figure 4-6. These curves are not exactly linear in the log-log form, but it is possible to approximate them segment by segment by long linear relations, i.e., relations of the form:

$$\log (\text{Damages}) = \log A + B \log P \text{ or } D = AP^B$$

For the segments labelled (1) ($.5 \leq P \leq 1.0$) and (2) ($.25 \leq P \leq .5$) in Figure 4-6, the linear approximations are

(1) $D = 1800\ P^{-2.49}$

(2) $D = 2260\ P^{-2.16}$

Since the cost function we have estimated above is in terms of average annual costs per inch per mile, we need to convert to total annual costs by

---

1/ In an attempt to test these results using a much larger sample, we calculated costs per inch per mile (averaged over the last three years) for all the cities responding adequately to our mail questionnaire. These were compared with information on daily average January temperatures and on the largest snowstorm each city's officials reported expecting (divided by 24). The results did not confirm our small sample results. It appeared that the largest storms reported as expected were either chosen rather arbitrarily, or were for so many different and unknown storm periods as to leave us with no useful relations. At lower levels of costs per inch per mile, we found a relation similar to the one behind Figure 4-5, but this was not sustained at higher cost levels.

AVERAGE ANNUAL COST PER INCH OF SNOW PER MILE OF STREET AS FUNCTION OF "REMOVAL" CAPABILITY

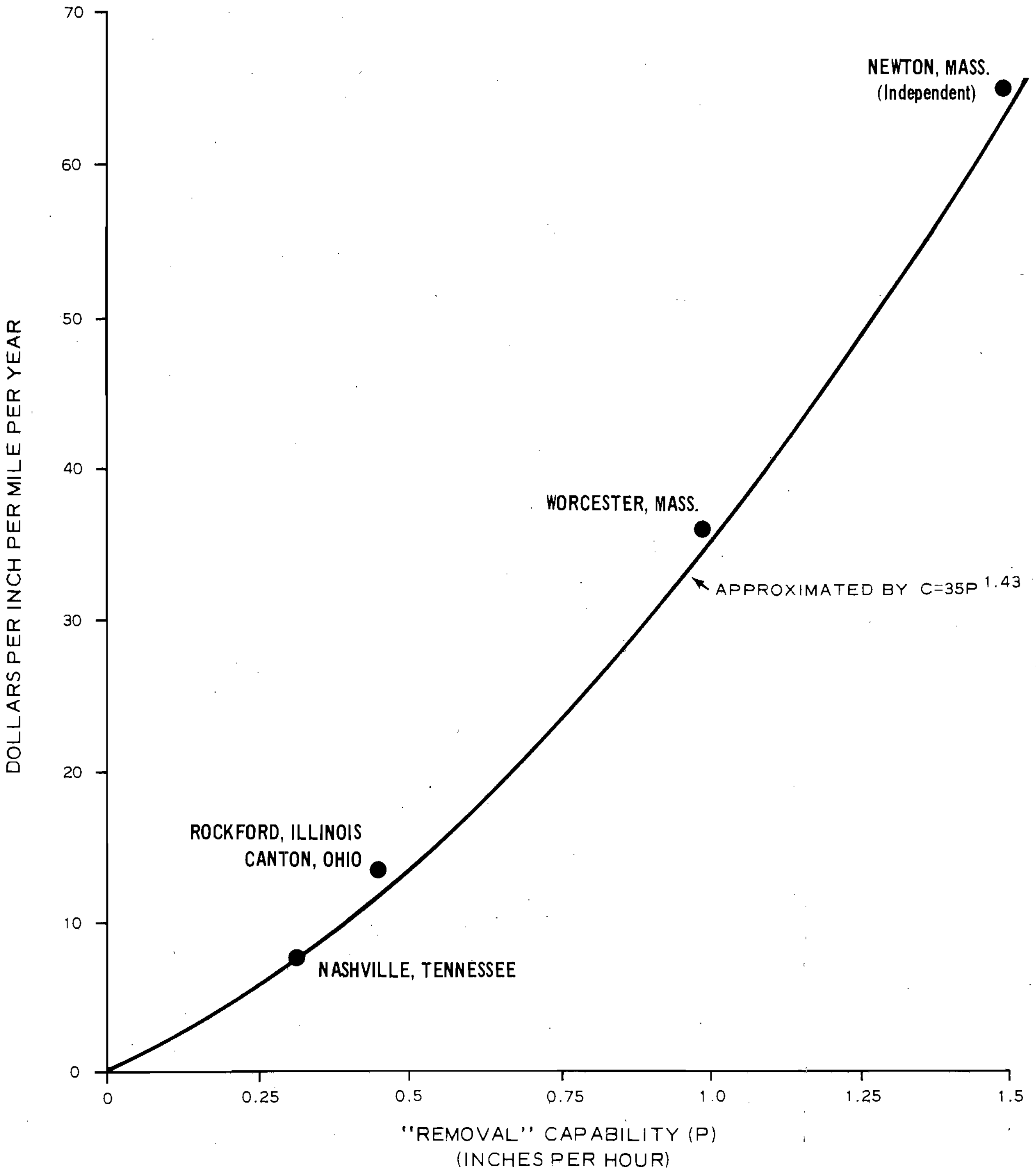


FIGURE 4-5

multiplying for each city by average annual snowfall and total miles of street maintained.1/ For each city, then, the cost function is also of the exponential (or log linear) form

$$C = GP^{1.43} = 35 \times F \times M \times P^{1.43}$$

where F = average annual snowfall;

M = miles of streets maintained.

Such a total annual cost function is shown in Figure 4-6 for Nashville. Its equation is:

$$C = 8600\ P^{1.43}$$

In order to choose the optimal level of P, we need to set the negative of marginal damages equal to marginal costs. In general terms, using the notation above, we have at the optimum P*:

$$-\frac{dD(P^*)}{dP} = \frac{dC(P^*)}{dP}$$

or $$-AB(P^*)^{B-1} = 1.43\ G(P^*)^{.43}$$

So that we may find P* from:

$$\log P^* = \frac{\log\ [-AB/1.43G]}{(1.43 - B)}$$

In Figure 4-7, we graph the marginal cost and damage curves corresponding to Figure 4-6. (We also give their formulae.) The optimal value of P is about .41, determined by the intersection of the marginal cost curve and the negative of the marginal damage curve corresponding to segment (2) ($.25 \leq P \leq .5$) of the total damage curve approximation.

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1/ In the example we use the average annual snowfalls from the generated hourly records. This puts cost and damage functions on the same basis. We use miles of streets from the interview results with no adjustment for multi-lane streets or urban thruways.

# NASHVILLE: ANNUAL COSTS AND LOSSES AS FUNCTIONS OF REMOVAL CAPABILITY (HIGH DEFERRAL RATE)

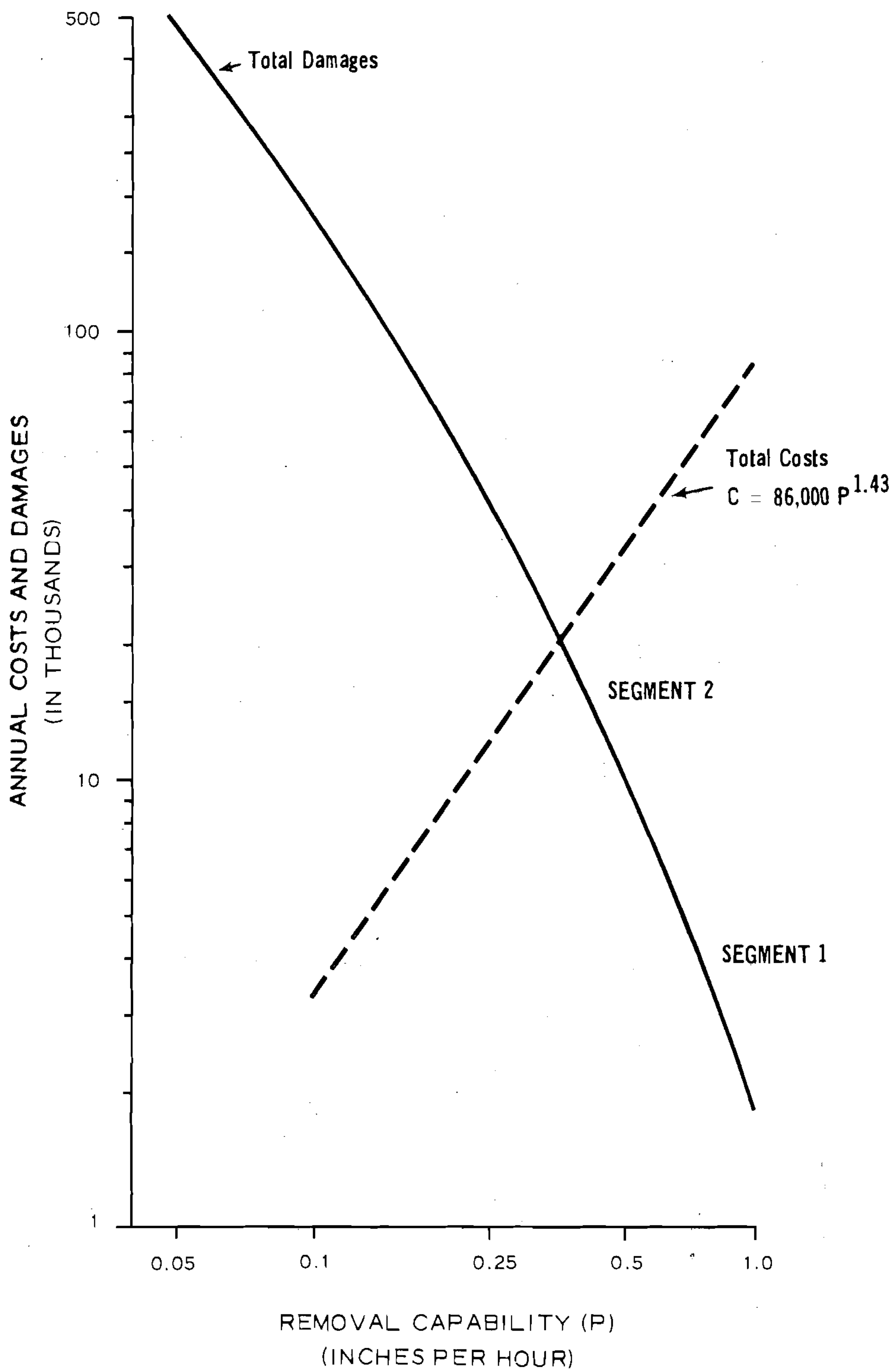


**FIGURE 4-6**

(Notice that the negative of the marginal damage curve corresponding to segment 1 ($.5 < P < 1.0$) intersects the marginal cost curve outside that segment, so that the intersection should be ignored.)

Before summarizing the results of similar computations for all four cities for both low and high assumptions about the extent to which "lost" production and sales are simply deferred to later periods of less than full employment, we recall that because the average annual damages were quite large (for small P) and highly variable, we suggested the desirability of including in the damage function some measure of that variability. To illustrate the effect of such a move, we have calculated optimal P's for damage functions based on expected annual damages plus one half of the standard deviation of annual damages, as well as for the simple expected annual damage function alone. These results are set out in Table 4-6, where we show for each city the key parameters of damage and cost functions, the optimal removal capability, P, and the value of P taken from Figure 4-4, used in estimating the original unit cost curve. While none of the results are particularly startling, several comparisons are of interest. First, the calculated "optimal" P's do not agree well with the P's estimated from Figure 4-4 for any single choice of p and damage function form. Thus, for Nashville and Evansville, agreement between these two numbers is closest for p = .9, and using expected damages only. Under those same conditions, agreement is least good for Worcester and Rockford. For Rockford, the closest fit is for P = .1, using expected damages only; for Worcester, P = .1, using expected damages plus ½ the standard deviation. No pattern seems detectable in these discrepancies.

## NASHVILLE: MARGINAL COSTS AND LOSSES AS FUNCTIONS OF REMOVAL CAPABILITY

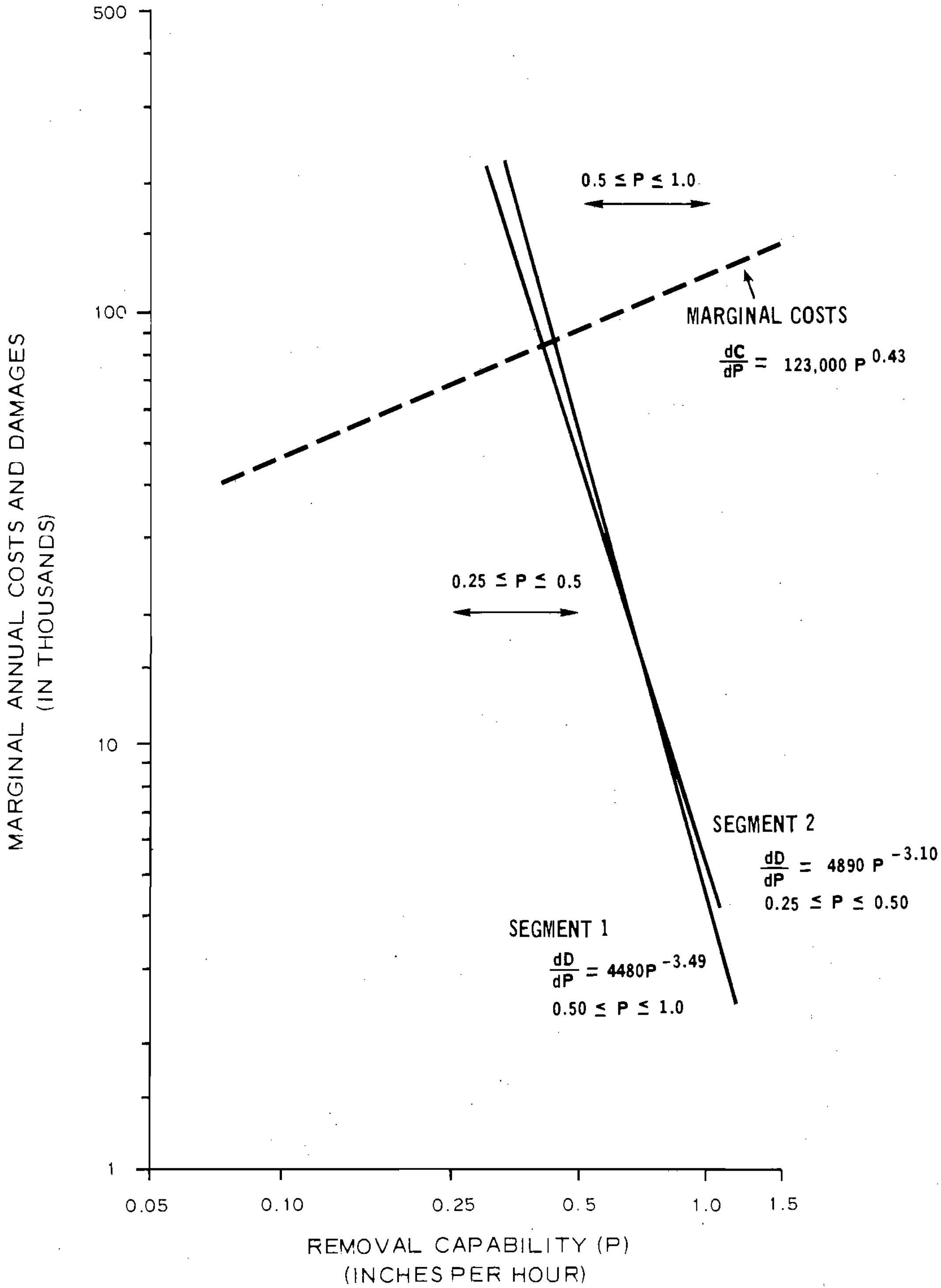


**Figure 4-7**

Table 4-7

Results of Applying the Model of Adjustment Choice

| City | ρ 1/ | B | A | G | Form of D(P) 2/ | P* | P from Figure4-4 |
|---|---|---|---|---|---|---|---|
| Evansville | .1 | -2.60 | 10,100 | 152,880 | μ | .591 | .33 |
| | .9 | -1.85 | 3,000 | 152,880 | μ | .326 | |
| | .1 | -2.41 | 25,800 | 152,880 | μ+1/20 | .720 | |
| | .9 | -1.71 | 7,230 | 152,880 | μ+1/20 | | |
| Nashville | .1 | -2.59 | 13,800 | 86,000 | μ | .736 | .33 |
| | .9 | -2.16 | 2,260 | 86,000 | μ | .407 | |
| | .1 | -2.50 | 35,600 | 86,000 | μ+1/20 | .922 | |
| | .9 | -2.26 | 4,100 | 86,000 | μ+1/20 | .497 | |
| Rockford | .1 | -2.78 | 5,250 | 341,880 | μ | .434 | .45 |
| | .9 | -2.51 | 1,350 | 341,880 | μ | .283 | |
| | .1 | -5.51 | 1,350 | 341,880 | μ+1/20 | .547 | |
| | .9 | -2.44 | 2,190 | 341,880 | μ+1/20 | .312 | |
| Worcester | .1 | -2.86 | 208,300 | 831,490 | μ | .851 | 1.0 |
| | .9 | -2.84 | 32,300 | 831,490 | μ | .549 | |
| | .1 | -2.73 | 350,000 | 831,490 | μ+1/20 | .949 | |
| | .9 | -2.77 | 52,000 | 831,490 | μ+1/20 | .605 | |

1/ ρ = the fraction of lost production/sales deferred to periods of less than full employment.

2/ μ = expected annual damages alone.
μ+1/20 = account taken of annual damage variability through inclusion of ½ the standard deviation.

Second, and more important, the optimal P's are quite sensitive both to the deferral assumption and to the form of the damage function. Thus, changing the deferral assumption from p = .1 to p = .9 and using expected damages only, the optimal value of P falls by a factor of about .55 (.65 for Worcester). For p =.1, taking account of the standard deviation of annual damages, results in an increase of about 25 percent in the optimal value of P (10 percent for Worcester).

The differences between the cities for any particular combination of p and damage function form are traceable to differences in "destiny" (basically the relation between population and road miles) or to the recorded snowfall pattern. Thus, Evansville and Nashville have very similar snow environments according to our generated records, but Nashville has roughly twice as many people per mile of streets maintained (630) as does Evansville (290),1/ and the optimal removal capability for Nashville is about 1.25 times that for Evansville under all four combinations of assumptions. On the other hand, Evansville and Rockford are similar in terms of population per mile of street maintained (both about 290), but Rockford has both a higher average annual snowfall and a lower optimal removal capability. This is explained by a difference in snowfall patterns, with Rockford having a pattern of hourly falls such that its losses fall relatively more rapidly as P is increased. Worcester with about seven times the average annual snowfall of Nashville is nonetheless similar to Nashville both in population per mile of streets maintained (520) and,

1/ Using 1960 population and 1969 street miles.

more surprisingly, in optimal values of P under different combinations of assumptions. This is evidence of the underlying similarity in the distributions of hourly snowfall rates; we have already noted that for both Worcester and Nashville, the 90 percent hourly fall was about 1.0 inch over our periods of record.

As we warned at the outset, our results are based on too many assumptions and approximations to be useful as planning guides even for the cities uned in the sample. It does, however, seem reasonable to conclude that decisions about the optimal level of adjustment to the urban snowfall hazard could be accomplished in this manner, given better understanding of the costs of maintaining a particular adjustment level.1/ In such an effort, it would probably be worthwhile taking into account the standard deviation of annual losses, though just how heavily this factor should be weighted is a matter for local decision.

On the other hand, it may very well be that the largest payoffs would come from applying this basic model to a very different kind of adjustment--that involving extensive shutting down of urban stores, schools, offices, etc., to allow a more leisurely attack on the accumulated snow. Estimating of costs of slower snow-fighting is straightforward enough, but determining the losses resulting from varying periods of shutdown would be difficult. One relevant thing we have already learned is the potential importance of allowing for deferral of "lost" production and sales. This would have an even more dramatic impact on the results of looking at the shutdown adjustment.

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1/ And, of course, given the assumption that the basic aim is to maintain normal traffic and routine.

## Appendix to Chapter 4

### Outline of Damage Computation Procedure

1. Data assumed to be the same for all years for a given city and choice of removal capability (P) i.e. for each "run":

   P = Snow removal capability
   LW = Trip lengths for workers
   LN = Trip lengths for nonworkers
   PW = Passengers per car
   PI = Lost wages parameter = fraction of value added accounted for by wages
   RO = Lost production parameter = fraction of "lost" production deferred to later period with less than full employment.

2. Data read in for each year of a given run:

   R = Radius of city
   W = Hourly wages (Constant Dollars)
   E = Employment
   A = Automobile registration
   Z = Commercial traffic volume as a percent of total traffic volume.

3. Snowfall data read in by hour for January, February, March, April, November, December over period of 11 to 19 years depending on city: F(t)

4. Temperature data available for every three hours of all days on which snow occurred over the period.

5. List of variables used in calculations:

   B = Speed factor exponent parameter
   TW = Number of work-related trips/hour
   TN = Non-work-related trips/hour
   D(t) = Hourly snow accumulations
   FST = Speed factor
   FVT = Volume factor
   VWO = Normal worker travel volume/hour [D(t) = 0]
   VNO = Normal nonworker travel volume/hour [D(t) = 0]
   BT = Absences (fraction of employment)

A2

EB = Absences (number)
EBB = Storm travel volume correction-work trips
VWT = Storm volume worker travel [D(t) > 0]
VNT = Storm travel volume-nonworkers [D(t) > 0]
VC = Commercial travel volume
SW = Trip speed-workers
SN = Trip speed-nonworkers
VA = Value of "lost production"
TC = Travel costs avoided by deterred workers
AWO = Cost of worker travel per mile [D(t) = 0]
ANO = Cost of nonworker travel per mile [D(t) = 0]
AWT = Cost of worker travel per mile [D(t) > 0]
ANT = Cost of nonworker travel per mule [D(t) > 0]
DWA = Damages due to worker absence ("lost" production)
DDN = Hourly damages due to deterred nonworkers
DH = Total hourly damages

6. Calculation of "normal" traffic volumes and costs (when D(t) = 0):

$$TW = .0625A^{.944}$$
$$TN = .947\ TW$$
$$VWO = TW\ (LW)$$
$$VNO = TN\ (LN)$$
$$VC = \frac{Z(VWO + VNO)}{1 - Z}$$
$$SN = SW = 15.5 + 9\ (LW)R^{-.990}$$
$$AWO = .08(SW)^{-.335} + .45(SW)^{-1.09} + \frac{W}{SW}$$

(Where the first term represents operating costs, the second expected losses from accidents and the third, the value of the driver's time.) ANO is evaluated similarly except W need not be used to value an hour of the nonworking driver's time. We did use W for lack of a compelling reason to use some other number.)

7. Conversion of snowfalls into accumulations:

$$D(t) = D(t-1) + F(t) - P$$
but $D(t) \geq 0$ always.

8. Calculation of impact of snow accumulation on traffic speed and volume in hour t.

**a)** If temperature $\geq 25^{o}F$, B = .225
If temperature $< 25^{o}F$, B = .239

A3

b) $FST = e^{-BD(t)}$

(note that if $D(t) = 0$, $FST = 1$; as $D(t) \rightarrow +\infty$, $FST \rightarrow 0$)

c) $FVT = 1.0 - \frac{.022\ D(t)}{FST}$

(But FVT is constrained to be always $\geq 0$.)

9. Calculation of impact of snow accumulation on worker absences:

a) $BT = .0015\ [3D(t)]^{1.696}$

(But BT is constrained to be always $\leq 1$.)

b) $EB = E(BT)$

c) $EBB = \frac{(EB)\ (LW)}{PW}$

d) $VWT = VWO - EBB$

(But VWT is constrained to be always $\geq 0$.)

10. Calculation of nonworker traffic volume during storm hour t:

$$VNT = FVT\ (VNO)$$

11. Traffic costs in storm-hour t ($/mile):

$$AWT = .08\ (SW \cdot FST)^{-.335} + .45\ (SW \cdot FST)^{-1.09} + \frac{W}{SW \cdot FST}$$

(Similarly for ANT.)

12. "Lost" production damages due to workers deterred by storm from travel to work:

$$VA = \frac{(W \cdot EB)}{1 - PI}$$

$$TC = EBB\ (AWO - \frac{W}{SW}$$

$$DWA = VA\ (1 - RO) - TC$$

A4

13. Other hourly damages:

CHW = VWT (AWT - AWO) increased worker travel cost

CHN = VNT (ANT - ANO) increased nonworker travel cost

CHC = VC (AWT - AWO) increased commercial traffic travel cost

$$DDN = \frac{(VNO - VNT)\ (ANT - ANO)}{2}$$

(valuation of nonworker trips prevented)

14. Total hourly damages:

DH = (HW + CHN + CHC + DWA +DDN)

# CHAPTER 5

## MUNICIPAL SNOW HAZARD ADJUSTMENT

David G. Arey

In this chapter, we focus our attentions on two related aspects of the urban snow hazard problem: This first is the nature of the organizational response to snow events, and the second is the structure of the costs of various combinations of responses and the way in which these costs are aggregated and expressed in a common measure of snow control.

In the Fall of 1968 questionnaires were mailed to the street superintendents of about 300 communities in the United States. The communities were chosen on the basis of their size, greater than 10,000 population, and their location in regions of the country which experience snowfall with some annual regularity. Questionnaires were returned by 178 communities. Not all questionnaires were completely filled in so that the number of respondents varies in many of the simple tabular analysis presented below. Out of the 178 questionnaires returned we were able to glean 48 that were filled in with sufficient detail so that the results could be used in an analysis of cost for snow control.

In addition to the results from the mail questionnaire we have used data provided by the intensive interviews undertaken in the six-city sample described in Chapter 1.

### Organizational Responses to Snow Hazard

The term organizational response is used to designate any action which can be taken by administrators of snow control programs which does not involve equipment and its use.

The simplest and perhaps most elementary of policy actions is establishing interdepartmental cooperation in the city government to better deal with the snow hazard. Expectedly, this was the most frequent organizational action of all with 103 communities (70%) having a formal policy of interdepartmental cooperation out of the 149 communities which responded to that particular question.

The second most frequent policy action was the creation of an authority to declare "snow emergencies" during which special rules apply to traffic and motorists. There were 100 communities (64%) in which this authority existed out of 157 responding to that particular question. The kind of legal modifications reported are shown in Table 5-1.

TABLE 5-1

ACTIONS TAKEN DURING "SNOW EMERGENCIES"

| Type of Action | Communities Number | % |
|---|---|---|
| 1. Parking bans as only action | 23 | 23 |
| 2. Early plant, office or store employee dismissal as only action | 6 | 6 |
| 3. Combinations of such things as 1 and 2 above, and requiring snow tires, designation of "snow corridors", etc. | 71 | 71 |
| Total: | 100 | |

A more sophisticated step for a community to take, but we think an important one, is the creation of a printed "snow plan" or "standard operating procedure" for organizing the community's efforts in snow control. Of the 148 communities which answered a query regarding printed plans, 81 (54%) had a plan and 67 (46%) did not. The content and meaning of these plans are discussed later.

Costs of Snow Control

A look at the structure of snow control costs may indicate the most fruitful areas for further analysis of the total costs of snow control. From interview information in the six-city sample, it is clear that of the three categories of labor, equipment and materials, materials are most important, followed by labor and then by annual equipment expenses (Table 5-2).

TABLE 5-2

MUNICIPAL SNOW EXPENDITURES FOR WINTER OF 1968 - 1969 IN SIX CITIES (in thousands of dollars)

| CITY | LABOR | EQUIPMENT | MATERIALS | TOTAL |
|---|---|---|---|---|
| Worcester | 110 | 75 | 227 | 412 |
| Canton[1] | 40 | 28 | 122 | 190 |
| Rockford | 70 | 3 | 60 | 133 |
| Utica | 32 | 21 | 48 | 101 |
| Nashville | 19 | 2 | 12 | 33 |
| Evansville | 4 | 8 | 6 | 18 |
| TOTALS | 275 | 137 | 475 | 887 |

[1]1967-68 data

This tabulation gives us a starting point for our investigation of the costs of snow control. If costs are to be reduced, then the area of materials - largely chemicals - is a possible place to begin. The question was raised as to whether or not the variation in use of chemicals, along with variations in the kinds of equipment used by communities, has any bearing on the average cost of the snow control program given a set of consistent objectives regarding the desired snow removal capability of each city in our survey. The assumption is made that each community is spending at least as much as it needs to meet its own goal regarding snow control - or that it has achieved its goal to the extent that it believes additional expenditures will not be beneficial.

The costs of snow control are borne mainly by the community at large via the actions of municipal government. An effort was made to discover the extent of this cost and the reasons for its variation from place to place. The measurement used to compare costs was dollars per inch of snow per mile of street plowed in an average year. This figure was compiled for 48 of the 176 sample cities by calculating average snow expenditures of the past five years, then dividing this quotient by average snowfall in inches, and finally dividing again by the number of street miles cleared, plowed or treated by each community.1/ The first step in this calculation was done to smooth out possible years of exceptional expenditure for capital goods which might not have been directly related to a single year's expected snow fall. This statistic is an artificial figure in which the exceptional costs and snow falls have been smoothed over five snow seasons. Even with these steps taken to smooth the data there were considerable variations, see Table 5-3.

In effort to account for the variation in the inch-mile costs, an elaborate, but unfortunately inconclusive, linear regression model was designed to determine whether or not the differences in costs could be explained by such variables as congestion of traffic in normal times, the snow fighting strategy used (i.e., salting versus plowing), whether or

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1/ Average Annual Cost per inch per mile $\equiv \dfrac{\sum \text{Costs over 5 years}}{\sum \text{Snowfall over 5 yrs} \cdot \text{miles of street plowed}}$

TABLE 5-3. FIVE-YEAR AVERAGE COSTS OF SNOW CONTROL PER INCH OF SNOW PER MILE OF STREET CLEARED

| COMMUNITY | COST/INCH/SNOW/STREET MILE CLEARED (5 year average; $) |
|---|---|
| 1. Auburn, Kansas | 1.31 |
| 2. Kingsport, Wash. | 2.00 |
| 3. Prairie Village, Kansas | 2.05 |
| 4. Crystal, Minn. | 2.14 |
| 5. Wallingford, Conn. | 2.29 |
| 6. Park Ridge, Ill. | 2.49 |
| 7. Parsippany/Troy Hills, N.J. | 2.86 |
| 8. Upper Arlington, Ohio | 2.96 |
| 9. Elgin, Ill. | 4.18 |
| 10. Florisant, Mo. | 4.44 |
| 11. Skokie, Ill. | 4.45 |
| 12. West Hartford, Conn. | 4.50 |
| 13. Haverhill, Mass. | 4.53 |
| 14. Bloomington, Minn. | 4.70 |
| 15. Norfolk, Virginia | 4.71 |
| 16. Muskegon, Michigan | 5.80 |
| 17. Hamden, Conn. | 6.43 |
| 18. Alliance, Pa. | 6.50 |
| 19. Yakima, Wash. | 6.86 |
| 20. East Hartford, Conn. | 8.43 |
| 21. Port Huron, Michigan | 8.82 |
| 22. Natick, Mass. | 9.23 |
| 23. Erie, Pa. | 9.56 |
| 24. Ames, Iowa | 9.64 |
| 25. Kalamazoo, Michigan | 9.65 |
| 26. Syracuse, N.Y. | 9.92 |
| 27. Oshkosh, Wisc. | 10.02 |
| 28. Waukegan, Ill. | 10.31 |
| 29. Watertown, N.Y. | 12.66 |
| 30. Cincinnati, Ohio | 13.64 |
| 31. Sioux City, Iowa | 14.21 |
| 32. Poughkeepsie, N.Y. | 14.24 |
| 33. Durham, N.C. | 14.66 |
| 34. Evanston, Ill. | 14.70 |
| 35. Salem, Oregon | 15.00 |
| 36. New Brunswick, N.J. | 15.31 |
| 37. Needham, Mass. | 15.83 |
| 38. Milwaukee, Wisc. | 16.03 |
| 39. Greenwich, Conn. | 16.58 |
| 40. Kenosha, Wisc. | 16.63 |
| 41. Racine, Wisc. | 17.28 |
| 42. Ann Arbor, Michigan | 17.78 |
| 43. Alton, Ill. | 22.22 |
| 44. Wellesley, Mass. | 24.85 |
| 45. Rapid City, S.D. | 26.41 |
| 46. Saint Paul, Minn. | 26.84 |
| 47. Youngstown, Ohio | 49.91 |
| 48. Newton, Mass. | 53.48 |

not snow was removed, the frequency and relative severity of storms, and the variations in organization for snow fighting (i.e., the extent of planning, legal actions, inter-city coordination, etc.).

The results of this exercise were inconclusive with only 30% of the variation in costs explicable by differences in the variables. Nevertheless, some useful information was obtained from the results of the statistical effort by examining the possible reasons for its explanatory impotence. Three possible reasons emerge as to the model's failure to account for a significant proportion of the variation in snow control costs. The first is that there is undoubtedly a considerable variation in the way in which the costs of snow control are tabulated and reported in the cities.

In some municipalities careful efforts are made to separate snow control expenditures from other highway expenses faced by the community. The accounting problems confronting the typical operating department in any city government are numerous. As was demonstrated in an earlier Chapter, a significant part of this problem is the extent to which equipment is depreciated over time and the measurement of what constitutes "more than normal" labor costs in snow control situations. Added to these problems are the familiar difficulties associated with recording critical information during times of stress. Despite admonitions to the contrary1/ it is doubtful that many cities keep detailed records of separable snow control costs. Evidence from the questionnaire survey suggests that municipalities rely on <u>ex poste facto</u> estimations of snow control costs except in a few clearly separable categories of costs such as chemicals, single purpose snow control equipment, special overtime pay, etc. Despite the scholars desire for more consistent and comparable data it is not clear at this juncture that there high pay-offs to snow control managers which would result simply from better record keeping. Marginal returns to time spent in other organizational tasks are likely to be higher than those accruing to the record keeping effort as will be discussed later.

Another source of variation in the costs reported in the questionnaire involves the problem that while fiscal year costs and the costs incurred during a snow season may indeed coincide there is every reason to believe that we have a considerable number of cases in which calendar year costs were reported. This second piece of scholarly misfortune was perhaps unavoidable because of the calendar year orientation of most small city government accounting set-ups.

The second source of possible error is that our measurements of the factors influencing costs were inadequate or prone to mismeasurement. The mismeasurement of these factors is a result of several problems. Cities use multipurpose street equipment in a wide variety of ways and in numerous combinations with single purpose snow control equipment. For example, our survey asked for the number of trucks which each city operated and the amount of time these trucks were used in snow control activity. This at first seems a straightforward question. A moment's reflection on the variety of ways in which trucks can be used in snow control as individual pieces of equipment and in combination with other equipment suggests, however, that city to city comparison of the statistics on truck numbers and usage may be a fruitless task. Moreover, while the survey made an effort to segregate data relating to snow plows and chemical/sand spreaders, we believe that some double counting of these special purpose pieces of equipment and the figure for truck usage was inevitable on the part of the respondents.

Another phase of operations prone to mismeasurement was that relating to the mileage of streets plowed during snow storms. Clearly here is a further example in which the multitude of strategies open to managers prevents the presentation of a single unambiguous statistic. This might be said of a single city from storm to storm with the value of generalized data becoming less and less useful as time and numbers of survey sites increases.

Finally, part of the mismeasurement problem undoubtedly also relates to the kind of information systems which cities have for dealing with natural events and the costs associated with ameliorating these events. One may ponder whether or not cities know the crucial elements of the costs of snow control in anything more than a general way. For example, it may be that because of the many possible variations in the conditions of snowfall, its moisture content and accumulation, the acfompanying weather elements, such as wind and temperature, there may be little to be gained from using costs per average inch of snow as an analytic tool.

The third and related reason for the failure of our model to explain effectively the cost variations from place to place is that conventional hypotheses about snow control costs are somehow fundamentally erroneous. The leading source of doubt in the hypotheses which the model made an effort to test is our notions about the extent to which cost reduction can be accomplished by increases in the technological capability which a city brings to bear on the snow control situation. We take the ineffectiveness of our model as evidence that the mix of technology, in the form of equipment and street treatment materials, with organizational strategy and flexibility does not play itself out in the environment in any predictable way. For example, initially we believed that differences between places in the strategies and techniques of removal versus non-removal of snow, salting versus plowing, the use of snow routes as opposed to other shifts in travel behavior, would lead to predictable changes in street-mile costs of snow control. It now appears that the search for consistency is more complex than we first thought or that there is so much variation in the measurements and/or the making of measurements as mentioned above renders the search a hopeless task.

There are a great variety of ways in which resources may be combined with a great variety of objectives in the face of complex and ill-defined differences in snow environments. This produces a situation in which seeking a set of simple and consistent data which will point to the direction of cost minimization in snow control, is probably not justified by the returns to be expected from the effort.

Given the myriad ways in which the variations in snow conditions in the physical environment may interact with the numerous and complex means of snow control, the choice of a particular cost to minimize or effort to maximize becomes hazardous, if none the less pressing.

Let us assume for the moment that cities do not have highly accurate records of all the possible causes for variation in snow control cost. Further, let us assume that additional efforts along accounting lines to accumulate records may or may not pay off. If we combine these notions with our information regarding the general structure of the costs of snow control mentioned above, we may be able to provide some insight to the search for alternative ways of adjusting to the snow hazard.

Planning for Snow Control

In order to delve further into the possible sources of cost variation from city to city and to provide background for examining alternative adjustments to snow, a critical analysis was completed of the snow control plans in 16 cities. A list of these cities is shown in Table 5-4.

The typical snow control plan is an operations oriented document which tries by pre-consideration to minimize the confusion attendant with a snow

TABLE 5-4. LIST OF SNOW CONTROL PLANS REVIEWED

1. Alton, Illinois
2. Cincinnati, Ohio
3. Council Bluffs, Iowa
4. Dayton, Ohio
5. Decatur, Illinois
6. Detroit, Michigan
7. Durham, North Carolina
8. Joliet, Illinois
9. Kalamazoo, Michigan
10. Kansas City, Missouri
11. Norfolk, Virginia
12. Seattle, Washington
13. Souix City, Iowa
14. Tacoma, Washington
15. Trenton, New Jersey
16. Wilkes Barre, Pennsylvania

storm. The routes of each vehicle in the snow control effort is spelled-out. Specific personnel readiness and task assignments are listed. They are in essence a cook book of the quantities of men and material which are to swing into action at a time that higher authority deems appropriate. The performance of activities, according to plan, has been widely advocated yet we may wonder if the very existence of a plan might not deter policy makers from examining a wider range of choice, just as a recipe may deter the cook from wide ranging innovations.

Because plans for snow control are operations oriented, one would expect to find little information regarding a major cost item in the snow control budget - materials. We should think then that the minimization of labor costs would be the intent of making the plans. A search of the 16 plans for specific time saving strategies, or points of flexibility in the plans were changing events could be taken into account to maximize the speed of operations, was not as fruitful as might be expected. Only six out of the 16 plans mentioned operational speed or flexibility. This reinforces the observation made in Chapter 4 that there are many judgments related to specifying "relevant costs" in snow control. Again one may question whether or not the development of plans which specifically recognized the importance of time reduction, along with deliberate manipulation of removal capability, might be worthwhile.

Because of the cost structure, time reductions at given levels of adjustment might well be the criteria for judging different snow removal capabilities. For example, a piece of equipment that promises complete removal of snow at a large increase in the time required to do the task, is probably not as efficient (in terms of losses or damages avoided) as a piece which operates rapidly but at some level less than total clearing. The snow removal plan which stresses detail of clearing assignment (often a strategy favored because it likely reduces the number of complaints) probably leads to higher economic losses than a plan which increases the speed of the removal operation. The conscious effort to trade-off time and removal capability is almost wholly absent from the snow control plans reviewed.

A second area also related to the crucial aspect of time which receives little attention in snow removal plans, is the accurate prediction of snow amounts and especially time of arrival. One possible method for increasing accuracy would be the development of local meteorological models. If properly designed, such models could make use of relatively low cost data input from the weather network and produce output which, if it could improve the time estimation of the onset of snow and its rate of accumulation, would prove highly valuable indeed.

None of the plans which were reviewed suggested taking no action under certain conditions although the threshold for plan activation was shown to vary from place to place. To see if "do nothing" might be a viable strategy in some places, an effort was made to determine the relation between our previously cited cost data and weather conditions which would favor a strategy of allowing natural melting.

The snow melt potential of the 48 communities was determined simply from average daily temperatures in January. It was found that of the nine communities in the part of the county experiencing $10^{\circ}$ to $20^{\circ}$ average daily temperatures in January, six were above the median in terms of dollars expended per street mile per inch of snow, while only three were below. For the twelve communities in the region where temperatures in January average $30^{\circ}$ to $40^{\circ}$, the situation was reversed, there being eight places with less than median expenditures. In the transition zone between these two extremes where there is greater uncertainty regarding the efficacy of no expense strategy of natural snow control, the twenty-seven communities were as nearly divided about the median as possible, with thirteen below and fourteen above. (Table 5-5)

TABLE 5-5. MELT POTENTIAL AND COSTS OF SNOW CONTROL IN 48 COMMUNITIES

| Aver. Daily Temperature in Jan. | Communities Below Median Costs/Inch/Mile | Communities Above Median Costs/Inch/Mile |
|---|---|---|
| 10° - 20°F | 3 | 6 |
| 20° - 30°F | 13 | 14 |
| 30° - 40°F | 8 | 4 |

Our purpose in discussing these possibilities for modifying snow control plans has been to stress the need for a broader look at alternatives in meeting the snow hazard in conjunction with a more explicit recognition of the objectives of snow control. We conclude this chapter with a discussion of the possible implications of our findings for the general problems which the municipal government faces in dealing with the uncertainty of snowfall events.

## The Planning Process

The process by which municipal officials plan for the future in general has been well documented. The various bureaucratic departments of the city government which provide essential services compete for the revenues available on a year to year basis. The elected representatives of the public weigh the varying demands for services and choices of priorities are made. One of the characteristics of the public decision-making process at the city level of government is that long range plans are rarely made. Moreover, when they are made, as in the case of urban renewal for example, they are continuously modified in scope and content as time goes on.

The snow control services provided by municipalities are a good example of this process. Annual renegotiation of the budget, shifting demands or "requirements" for snow control and the constraints of personnel all contribute to the reduction of planning in its procedural aspects. Added to the planning difficulties of snow control management is the uncertainty introduced by the snow environment. There is a deceptive paradox in the snow environment which complicates the message which the manager must deal with in planning. This paradox is often absent or masked by time in other forms of man-environment relations. It stems from the fact that in most cases managers are sure that it is going to snow each winter but the amount, kind, and timing of snow storms are unknown. One might call this situation certainty compounded by uncertainty.

The question can be asked at this point whether additional information regarding (1) the costs and damage potential of snow storms, (2) the characteristics of snow control equipment and (3) the nature of the snow environment itself, will be of significant value in the face of the structural or political difficulties in allocating scarce financial resources amongst city services. One thing appears certain, the major points of flexibility in snow control planning are, first the target which management sets for itself in terms of the closeness to normal (non-snow) conditions which is to be striven for and secondly, the time required to achieve and maintain whatever snow control target is established.

In Chapter 4 we demonstrated that the problem of specifying the relevant costs and losses to compare is complex and not without its political implications. We might speculate that even if we could ignore the problem of interdepartmental competition for municipal revenues, there is insufficient information for making optimal adjustments to probabilistic snow events. However, it is apparent that seeking additional information is a costly process with very uncertain payoffs in the case of snow control.

We conclude here with a message similar to that of Chapter 4, that the municipal official must be willing to discuss (and even initiate discussion of) the objectives which are sought in any action program. Further, it is plain that the nature of the information collected by officials to justify public expenditure, must take into consideration the public's as well as the official's perception of the problem.

# CHAPTER 6

## THE IMPACT OF SNOWFALL ON MANUFACTURING AND RETAIL ACTIVITIES IN SELECTED CITIES IN THE UNITED STATES

Mark Blacksell

Throughout the Northern United States snowfall in winter is a fact of life, arousing a wide range of responses from the general public. Depending on what they happen to be doing, or want to do, people either welcome, deplore, or do their best to ignore snow.

There are two quite distinct and basically unrelated aspects to the problem of snow in urban areas, and each must be treated separately. First, and for the pruposes of this study, most important, whenever snow falls it causes a degree of dislocation in the functioning of the urban environment. Traffic tends to be delayed, schedules are disrupted and the level of irritation and frustration among the populous rises. The goal of all public snow removal policies and programs is to minimize the upset, but clearly even with the most strenuous effort, some measure of dislocation still occurs. One of the objects of this chapter is to try and establish the scale and importance of this disruption to a city's economy.

Aside from the disruption of day-to-day activities, snow, like almost anything else, creates a market for a whole range of consumer goods. Many retailers and some manufacturers depend upon its presence or absence at specific times in the year to generate business. The sales of snow tires, snow boots, skis, and many, many other products are dependent on snow for their very existence and the volume of trade in them is intimately connected to the pattern of snowfall throughout the winter.

It is vital, however, to make a clear distinction between the market for "snow goods" and the disruption caused by snowfall. These are distinct and mutually independent subjects and it is vital to emphasize that the costs of one cannot be set off against the benefits of the other. If a supplier of snow tires is unable to distribute his goods, because of snow-blocked roads and customers cannot buy them, because streets are impassable, sales will suffer, despite the fact that these are snow goods.

It was considered too large a task to investigate all the facets of business and commercial activity in the cities being studied and in any case it seemed doubtful, whether such effort would be well spent. For two reasons, attention was concentrated upon manufacturing and retailing. First, both are deeply dependent on efficient transportation systems, and the most serious hazard associated with snow is its capacity for disrupting transportation. Second, there are significant sections of both retailing and manufacturing that are involved in the snow goods industry, and they therefore provide an opportunity to study both the major aspects of the impact of snow on the urban environment.

Data Collection

Collecting data from individual manufacturers and retailers about the problems they faced through winter snowfall was extremely difficult. Very few of them considered snow as a single variable and therefore, any information collected on the subject tended to be widely scattered within the files of the business. This would not have presented in any sense insuperable difficulties, if there had been consistency in the way in which the information was recorded, but in fact there was unfortunately an extremely wide variation in the procedures adopted. In addition to this, for the vast majority of the firms and businesses interviewed, snow was a relatively minor concern, which was thought to have little direct effect on operations. As a result, it was generally found that minimal trouble had been taken to measure its impact in any way whatsoever, let alone in dollars and cents, and there was the continual danger of collecting subjective impressions, rather than hard facts.

Despite the lack of uniformity and the difficulties this was likely to pose for the survey, it was decided to construct a questionnaire for collecting the data. Ideally one would have liked to use a sample mail questionnaire for studying both manufacturing and retailing, since this is the most rapid way to cover the ground. This approach was used to survey a large number of manufacturing firms but no matter how one phrased the introductory letter, retailers were reluctant to release data on daily sales, without prior permission from their superiors, or a great deal of persuasion. Their response to a mail questionnaire was simply to ignore it. The only alternative, therefore, was to select a cross section of shops on the basis of: a) their location in the city; and b) their type; and to interview the managers in person. The drawback to this approach was the limited ground it proved possible to cover, and the impossibility of drawing an unbiased sample.

Although the method of administering the questionnaires was different in the two cases, the information and layout of the two questionnaires was basically the same. They both were designed to gather four different sets of information.

First of all it was necessary to establish some kind of background to the factory or shop, and in all cases data on the type of firm, the size of its labor force, average hourly wages and location were sought.

This section was followed by one which dealt specifically with any disruption caused by snowfall during the winter of 1968/69 (the interviews were conducted in the summer of 1969). Here one was trying to establish whether there had been production or sales losses that could be attributed directly to snowfall, and in the case of the shops, attempts were made to gain access to daily retail sales data, so that these could be checked against daily snow data.

The third section considered the whole problem of snow removal from the point of view of the individual firm. Questions were asked on the degree of satisfaction with the city's snow removal program; on costs, such as investment in material, equipment, and manpower, which had to be borne for snow removal; and on whether the winter weather conditions would ever influence a decision to move to another location.

The final section was concerned with the personal attitudes of the respondent towards snow and snowfall. Its purpose was to find out to what extent he or she considered snow an inconvenience; from what sources, if any, information about weather forecasts was obtained; how the respondent defined a heavy snow storm in terms of death; and how he or she assessed the disruptive potential of snowfalls of different character.

The range of data sought was intentionally extremely broad, but by attacking the subject on so many fronts, it proved possible to construct quite a comprehensive picture of the snow problem for each firm or business studied. Gaps in information for one section of the questionnaire were in many cases compensated for elsewhere. For example, even though a number of people interviewed had very little idea about the costs of snow removal and were unable to produce any figures for it, their replies to the section on attitudes to snowfall frequently gave a very clear indication as to the importance that the firm as a whole attached to snowfall.

Results of the Questionnaire Surveys

Altogether 259 mail questionnaires were distributed to manufacturing firms in the cities of Evansville, Greensboro, Duluth, Utica, and Canton.

All the cities were in the size range prescribed for the study, between 100,000 and 200,000, but their snowfall environments differed. Evansville and Greensboro both and an average annual snowfall of less than 10 inches; Canton received between 20 and 50 inches; and Utica and Duluth both had averages considerably in excess of 50 inches. As a result, all three of the crude snow environments defined - light, medium, and heavy, were sampled in the survey. For each of these cities, all manufacturing firms employing more than 100 were sent questionnaires and in addition a 10% random sample of those employing less than 100. The overall response rate was rather disappointing at 25% (64), but there was also considerable variation between cities:

Table 6-1
Manufacturing Questionnaires Sent and Received by City

| | Evansville | Greensboro | Canton | Utica | Duluth | Total |
|---|---|---|---|---|---|---|
| No. sent | 53 | 42 | 59 | 44 | 61 | 259 |
| No. replies | 16 | 12 | 11 | 12 | 13 | 64 |
| % replies | 30 | 28 | 19 | 27 | 21 | 25 |

There was, however, a reasonable response from firms in at least one city in each type of snow environment, and for the purposes of illustrating between group variation in the tabulations, Evansville, Canton and Utica were chosen as examples.

It was also possible to break down the questionnaires according to the size of firm. The number of replies was such that it was only practicable to sub-divide the responses into three groups:

Table 6-2
Manufacturing Questionnaires, by Size of Firm

| | less than 100 employees | 100-999 | greater than 1,000 employees |
|---|---|---|---|
| No. sent | 83 | 154 | 22 |
| No. replies | 11 | 34 | 19 |
| % replies | 12 | 21 | 86 |

As can be seen from Table 6-2, there was varying representation for each of the three groups, but effects of firm size should still be measurable.

The tabulation of the data from these questionnaires is set out in Appendix 2.

The retail questionnaire was essentially the same in design as the manufacturing one, except that it was not mailed, but was administered by personal interview. An attempt was made to select stores representing a wide range of retail outlets, and both downtown and out of town locations were used, so that there would be some chance of showing variations within the urban area. The type of information gathered was virtually identical to that from manufacturing firms, except that instead of daily production data, an attempt was made to find out daily sales information for the winter of 1968-69.

The Analysis of the Results

Probably the most significant and best supported fact to emerge from the survey was the relatively small problem that snow appeared to pose for all types of manufacturing industry. Few, if any, of the firms interviewed felt seriously threatened by snow and the majority took only the most rudimentary precautions to ensure that operations were not disrupted. Also there was no conclusive evidence to support the contention that attitudes or actions were significantly altered by the actual snow environment. This latter assertion may appear surprising, but as will be seen, it is supported by various sets of information from the questionnaires.

It has just been suggested above that winter snowfall is not an important influence on the present structure and operation of manufacturing industry in the North-Eastern and Mid-Western United States. Evidence to support this usually came very early in the questionnaire, when the respondent was asked to rank six potential hazards--drought, flooding, influenza, snow, strikes, and tornado. The answer to this question are summarized in Table 6-3. This sets out the number of first, second, and third place rankings each of the six hazards received, with the results further broken down by city and size of firm. Only the first three rankings are included in this summary table, since the response rate for the rest was so poor that it was felt that they yielded very little useful information. There were frequent comments to the effect that the fourth, fifth, and sixth choices did not really affect the firm in any way and could have been placed in any order.

The first point to emerge from this table is the overwhelming importance of three hazards, influenza, snow, and strikes, as compared with the rest. Their dominance is clear in all three sections, and, when first place rankings are considered they all but exclude the other possibilities. If influenza, snow, and strikes are looked at in more detail, once more a definite pattern emerges. Influenza is the most serious problem; 42% of the firms (27 out of 64) put it in first place, whereas, snow - 26% - comes a poor second, only marginally ahead of strikes - 22%.

Although this question was not pursued in great detail in the mail questionnaire, more detail was sought in personal interviews with some firms. Not surprisingly, few had detailed comparative records, but one large textile firm on the outskirts of Nashville, Tennessee, had made an analysis of this subject quite independently. Their survey showed that influenza was ten times more disruptive, when measured in terms of loss of production due to absenteeism, than was snow and ice. Even allowing for Nashville's southerly location this was a striking result. One overall conclusion was inescapable; illness and labor problems had a direct bearing on the efficiency of firms, but natural, climatic hazards appeared to have little overt impact. However, if the natural, climatic hazards (drought, flooding, snow, and tornado) were looked at in isolation, snow emerged quite clearly as the one perceived as

Table 6-3
The ranking of hazards -a) first place

| | drought | flooding | influenza | snow | strikes | tornado | no response |
|---|---|---|---|---|---|---|---|
| total | 0 | 0 | 27 | 17 | 14 | 3 | 3 |
| Evansville | 0 | 0 | 7 | 0 | 6 | 2 | |
| Canton | 0 | 0 | 3 | 1 | 6 | 1 | |
| Utica | 0 | 0 | 7 | 4 | 1 | 0 | |
| 100 | 0 | 0 | 1 | 6 | 0 | 1 | |
| 100-999 | 0 | 0 | 16 | 7 | 9 | 1 | |
| 1,000 | 0 | 0 | 9 | 2 | 5 | 1 | |
| **-b) second place** | | | | | | | |
| total | 3 | 8 | 15 | 22 | 7 | 3 | 6 |
| Evansville | 0 | 2 | 4 | 6 | 0 | 1 | |
| Canton | 1 | 2 | 2 | 6 | 0 | 0 | |
| Utica | 0 | 2 | 2 | 3 | 4 | 0 | |
| 100 | 1 | 1 | 4 | 1 | 0 | 1 | |
| 100-999 | 2 | 6 | 8 | 13 | 2 | 0 | |
| 1,000 | 0 | 1 | 2 | 7 | 4 | 2 | |
| **-c) third place** | | | | | | | |
| total | 2 | 10 | 7 | 11 | 6 | 10 | 18 |
| Evansville | 0 | 3 | 2 | 3 | 0 | 3 | |
| Canton | 1 | 2 | 0 | 3 | 1 | 3 | |
| Utica | 1 | 2 | 2 | 3 | 1 | 1 | |
| 100 | 0 | 2 | 1 | 0 | 1 | 1 | |
| 100-999 | 2 | 4 | 2 | 7 | 3 | 7 | |
| 1,000 | 0 | 3 | 4 | 4 | 1 | 2 | |

being the most potentially disruptive.

Within the overall picture there were some interesting regional, and between firms, variations, but it must be emphasized here that in many cases the sample was so small, that it was dangerous to read too much into the results. The pattern which emerged between cities in the three different snow environments was somewhat contradictory. Of all the five cities studied Utica had the heaviest snowfall in the winter of 1968/69 with 100 inches, but however one manipulated the figures, influenza emerged as being a decisively more serious hazard. On the other hand, in Duluth, which only had 66 inches of snow in 1968/69, 11 out of the 13 firms that replied put snow in first place. For the more southerly cities, none placed snow in first place, although with the exception of Evansville where it was marginally dislodged by tornado, it emerged as the most threatening climatic hazard.

When the returns were analysed by size of firm, a striking pattern emerged. There was a clear trend towards less importance being attached to snowfall as the size of individual firms grew. This is a clear reflexion of the simple fact that size and flexibility would seem to go hand in hand. The smaller a concern is, the less able it is to bear short-term dislocation of the transportation system. Its operations will tend to be short-term, perhaps even on a day to day basis, and any disruption to deliveries, supplies or the flow of customers will tend to result in total loss of business, rather than deferred sales. The pattern that emerged from the survey, therefore, showed that 60% of the responding firms employing less than 100 perceived snow first, compared with 21% in the 100-999 range and 11% in the 1,000 plus group. By comparison influenza was rated most serious by 50% of all firms with more than 100 employees, but by only 10% of those with less than 100. Once again, however, snow emerged was rated most serious by 50% of all firms with more than 100 employees, but by only 10% of those with less than 100. Once again, however, snow emerged in all three groups as being far and away the most seriously perceived climatic hazard.

Having discussed snow in relation to a variety of other hazards, it seems logical to try and probe the basis for these results in detail. Section 4 of the questionnaire was devoted to questions about people's attitudes towards different types of snow conditions and about how they responded to the threat of snowfall.

The survey showed two things very clearly: first that nearly every firm (95%) was interested enough in snowfall to listen to a weather forecast of some description and, second, that each firm (93%) had some opinion that they wished to express about the snow environment. However these opinions varied considerably and the only clear overall conclusion that emerged was how few people (6%) wished there were more snow in winter. For the rest, the largest group (38%) wanted no change, while 30% wanted less snow and 14% wanted to eliminate it altogether. 12% made no reply. It is difficult to make any precise statements about attitudes to the snow environment from these figures, but from additional comments volunteered, it appears that while many people enjoyed snow for recreation, they would be only too pleased to see a reduction in the amount falling in the cities. The prospect of being isolated at home or anywhere else appeared to be an unsavoury one, even if there were no pressing need to travel. It is not unreasonable to suggest that the obvious avidity with which people kept up on weather forecasts was a result of an underlying concern about the problems snowfall could pose for travel. By far the most popular source of information was T.V. or radio (42%), but almost as many firms (38%) were prepared to check this out by maintaining direct contact with the local airport.

Despite the obvious concern, however, only one of the firms surveyed, a large electronics concern in Utica, found it worthwhile paying for the services of a professional meteorological consultant, even though the cost of this service is rarely more than $200 a year.

To this point there has been a tacit assumption that snowfall conveyed the same image to a firm, whereever they happened to be located, but definitions as to what constituted a heavy snowfall varied considerably. Rooney has shown that any accumulation of over 2 inches in one storm is liable to cause appreciable inconvenience, and any amount over 5 inches is liable to cause total disruption. When the respondents were asked to define "a heavy snowstorm" the results varied in any interesting way with the snow environment. In Evansville, the majority of those who replied thought that a 2 inch storm was heavy. In Canton, the majority thought that a 6 inch storm was heavy; while in Utica, 4 out of 12 respondents thought a 12 inch storm to be heavy and 5 out of 12 believed 2 feet to be nearer the mark. Quite clearly there was a strong relationship between the total annual amount of snow and the generally accepted definition of a heavy storm.

However, when one also considered the time of day when snow fell, and the type of snow conditions, there emerged a very much less easily interpreted pattern. Overall, it may be said that the form that a storm took was always viewed as more important than the time when it fell in determining disruption, thus that snow with high winds and drifting and freezing rain were clearly seen as the most dangerous forms. The time of snow fall was the second most important factor in its disruption. For manufacturing firms, the most inconvenient time was at night, followed by morning and afternoon falls, obviously the reason being that the disruption of movement in the course of a day generally decreased the later the storm started. Finally, the least disruptive conditions were those after the storm, when it started to thaw.

Thus far this analysis has concentrated solely on the perceived dangers of snowfall, no attempt has been made to measure the actual costs to individual firms. Theoretically total costs of snowfall can be stated as the sum of all losses plus the costs of adjustment; optimum investment is the amount which minimises this total sum of costs. However, there are considerable difficulties to be overcome before such a function can be realistically quantified.

First of all the individual firm is never made to bear directly the full cost of losses and adjustments due to winter snowfall. Indeed the whole of the private sector is shielded from the worst effects of the hazard by the provision of public snow removal programs. Industry in particular represents a powerful pressure group in any city and it is therefore able to exert considerable influence on local authorities to provide the kind of snow-removal program that will put its own level of inconvenience at an absolute minimum. If roads are not passable in winter there is an immediate outcry and local authorities have to make snow clearance a top priority since private employers will tolerate no obstruction or delay. In any case there is no question but that individuals never admit to a realistic contribution, because they feel that they can always chronically underestimate, since the local authority will clear the streets in any case. This emerged strikingly from the survey, for when the firms were asked whether they thought the city ought to have a better snow removal program, 45% answered in the affirmative. However, when then asked if they thought it would be worth their while to contribute more to the local taxes for this purpose, only 10% answered yes.

This universal difficulty tends, therefore, to make cost assessment suspect from the outset, but a second problem is the extremely incomplete nature of much of the direct expenditure data. Nearly all the firms keep some records of the amounts spent on clearing agents such as salt and sand

and preventive measures such as the buying of snow tires, but labor costs and costs for use of equipment are not often recorded separately and these represent the bulk of the expenditure. Snow removal usually is costed under the general heading of maintainance, and for most firms it poses a small item of expenditure even in this sector.

For these reasons the only practicable outlet seemed to be to accept each individual firm's estimation of the amount spent on snow removal for the winter of 1968/69, even though it was quite obvious that there would be considerable variation in the derivation of these figures.

When one comes to examine losses in production due to snowfall, there would appear to be no way in which really accurate estimates can be made. The only fully reliable way to attribute losses in production to snowfall, is if the firm has been forced to close completely. Even such a situation may not result in total loss, since production may well still be madeup over a period of time. In any case, although some of the firms surveyed had been forced to close at one time or another for periods up to 48 hours, not one had had to do so in the winter of 1968/69. During that winter, 71% of the respondents experienced a production loss of under 5% on one day, but in most cases this was within their overall working margin of loss and could easily be made up. The same was also true of the few cases where time lost due to snow was greater. Not a single firm admitted to a permanent loss in production. Nor were they, in many cases (46%) forced to pay for increased absenteeism, since, even on snow days, employees not coming into work received no pay. Indeed, there was no evidence to show that a firm suffered any direct losses other than the very small amounts which were expended on adjustment. It appears that as far as manufacturing firms are concerned, the costs are borne almost exclusively by the public sector and by individual workers.

There were two main ways in which firms combatted snow: either by spreading salt and chemicals, or by using heavy equipment to remove it. The only other alternative mentioned was by a firm in Rochford, which heated the sidewalk outside its main office block at an average cost of $600 a year. Of the two major methods, spreading salt and chemicals was by far the most popular and the majority of firms seems to resort to this method exclusively. Only 10 firms (15%) did not purchase some form of melting agent on an annual basis and half of these were in Evansville. Indeed, for many of the firms outside the heavy snow areas the purchase of salt and chemicals was virtually the sum total of their expenses on adjustment to snow hazard. Of those surveyed who did use any available trucks or tractors on the site, rather than specialist equipment. Nevertheless, 28 firms (44%) did own snow plows. All those with more than 100 employees in the heavy snow areas, Utica and Duluth, owned one as well as some in the medium snow zone, Canton and Rochford. However, in Evansville and Greensboro there was only one firm which had a snow plow. Equally, size of firm also affected the type of equipment owned: of the firms with less than 100 employees, there were only three that had direct access to a plow.

A somewhat surprising result from the survey was the small number of firms that sub-contracted snow removal. For shopping plaza's and local authorities this was frequently done, but only a quarter of the manufacturing firms used outside help. A number of firms were questioned on the matter and there appeared to be two main reasons for their reluctance. First there was the difficulty in finding contractors who were not already fully booked to local authorities on a long-term basis, and second most firms had maintenance crews and heavy equipment already available on the site.

<u>Retailing</u>

Although the basic questionnaire for gathering the information on retailing was exactly the same as the one for manufacturing, the results that could be gleaned from it were very much more limited. The total number of shops visited was only 32 and these were selected in such a haphazard way that any internal cimparisons were virtually impossible. However, the striking thing about the overall conclusions was the similarity to those from the manufacturing survey. Of the natural climatic hazards, snow emerged as clearly being the most dangerous, but it was still a poor second behind influenza in the overall rankings. An even greater percentage of retailers (43%) said that they would like the snow environment to stay the same and, of the rest, all would have preferred less snow or none at all. The shopkeepers also emerged as avid watchers of the weather forecasts of the T.V. 93% listened to this information daily and 52% said that they kept a detailed record of the weather so that they could make some assessment as to how it affected sales. The answers to the questions about which snow conditions they found most and least disruptive were even more clear cut than with the manufacturing firms. Freezing rain was almost universally hailed as the worst possible hazard, followed a long way behind by snow with high winds and drifting and snow falling in the morning. Snow lying or falling at night were clearly viewed as being the least harmful.

However, in complete contrast to the manufacturing survey the retailers emerged as being deeply concerned about lost sales. The managers of most types of shop firmly believed that the pattern of snowfall through the winter could significantly affect total sales. The next section considers this question in detail.

Variations in sales due to snowfall

The survey was plagued throughout by a great reluctance on the part of retailers to divulge anything but broad hints about their sales. Even where respondents were co-operative, they would only give percentage figures showing how much sales were up or down on the comparable day the year before. Luckily, however, a chain of department stores in Worcester agreed to give us their gross daily sales figures for both the winters of 1968/69 and 1967/68. It was an exceptionally fortunate chance since there were seven stores in the Greater Worcester area and one was thus able, not only to build up a picture of the individual store, but also a composite one showing retail behavior throughout the city.

It was found that there was a very distinct pattern in weekly sales overall and that this appeared only to be broken by the intervention of major public holidays such as Christmas. This pattern is shown in figure 1.

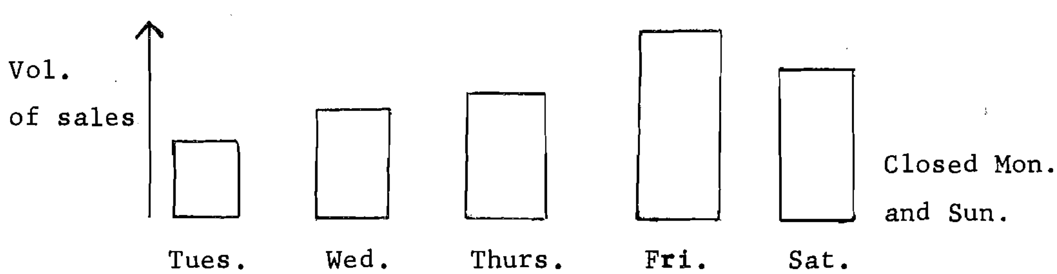


Figure 1

Diagrammatic picture of sales pattern for Worcester chain store

This pattern with a general build up through the week to Friday and then a slight fall in Saturday trade was repeated for all seven stores, although naturally the volume of trade at each varied considerably.

The data were then tested against the snow information for Worcester to find out whether snow storms caused either alteration in the balance of trade between stores, (eg: reducing the volume of the downtown location relative to the suburbs) or overall changes in the volume of sales, as compared with the equivalent day in the preceding year. In both cases there appeared to be little significant disruption. There was no evidence that relative sales between the stores were affected at all and only on February 10th, 1969, after there had been a 13.7 inch snowfall of the 9th, was there an overall reduction in sales of more than 3% on any given day over the same day the previous year. In this particular case sales were down 7% on Wednesday, February 10th as compared to Wednesday, February 11th, 1968. However, against this, one must set the fact that on Thursday, February 12th, 1969, sales were up 5% on the year before. Indeed, there was no evidence to point to anything but sales being simply deferred in this case and even this interruption to the general flow was unusal.

The experience at this chain of stores, however, may very well not be typical of all types of retail outlet. The fact that these were gross sales for a large store selling a very wide variety of goods may well have had two consequences. First, shoppers would tend to gravitate towards that type of store in snowy weather, because they could buy most of their goods there, rather than shopping around. Second, the wide range of goods would mean that a single figure for gross total sales could, in fact, hide important changes in the pattern of sales withing the shop.

The attitude of many store keepers towards the inconvenience of snowfall was colored by the fact that the presence or absence of snow in general, itself generated quite a large volume of sales in winter. For retailers marketing automobile accessories, snow related goods, such as snow tires and de-icing sprays, were important items of winter sales. Equally the footware industry counted on fall and early winter snowfall to boost sales of boots and heavy shoes. However, important as this market was to such shops, these sales are not related to our concern, the efficiency of the municipal snow-removal operations, except in so far as streets were not passable, when sales of these goods would suffer equally ith any others.

Summary and conclusions

Snowfall could theoretically have affected manufacturing and retailing in the United States in a number of ways, but in fact the only real problem was the restriction on free and easy traffic circulation and removal efforts were geared entirely to minimizing this dislocation. Even allowing for the inconvenience, the economic impact of snow on the privale sector was small and this was reflected in the rather ambivalent attitude towards it of the people interviewed. Most had no strong opinions about snow, although there was in general a desire to see rather less of it in winter, but it is worth pointing out that what concern there was tended to be with the form of the snow storm rather than with the snow itself. Once the ground was actually covered, snow appeared to create very few serious problems.

The main reason for the relatively minor impact of snow on the private sector, is that removal is accepted as a part of the public service to a city. Any local tax payer, and certainly a large contributor such as a factory, feels, quite justifiably, that he can put pressure on the city authorities to keep streets open at all times, irrespective of the cost. As a result he is almost entirely freed of any direct financial burden through snow. This was substantiated at all the shops and factories visited; in every case snow removal was a very minor item of expenditure, in many cases too small to demand separate calculation.

Despite all this, however, it must be stressed that snow storms still cause some urban disruption and both manufacturing and retailing do suffer some losses significant or really damaging. In most cases losses in production or sales are no greater than the variation generally accepted by a firm on its daily output and can easily be compensated for in normal working hours. Although the figures gathered were scanty, there was no evidence to show a fall off in turnover lasting more than one or two days and if one compared weekly totals with those for previous years, they were invariably improved.

In conclusion, urban snow in the United States cannot be classes as anything other than a minor inconvenience to either manufacturing or retailing. Even in heavy snow areas, the adaption of the city authorities and the general public to the hazard is such that private industry (both manufacturing and retailing) is shielded from all but the most minor effects.

# CHAPTER 7

## INDIVIDUAL ATTITUDES AND ADJUSTMENTS TO SNOW

Peggy Lentz and Duane D. Baumann

An individuals attitude toward snow may be influentail in the formulation and implementation of a public snow control program, and may influence his own strategy of adjustment, as well as his psychic well-being.

This chapter investigates the personal responses of city residents to the urban snow hazard, individual adjustments commonly adopted to the hazard, and attitudes toward urban snow control measures are explored within different snow environments. Our efforts were directed to four salient questions:

1. Does the amount of snowfall affect an individual's evaluative attitude toward his snow environment?
2. Does an individual's assessment of his snow environment display a seasonal shift, i.e., is snow more highly valued in summer than in winter?
3. To what extent does an individual's attitude toward snow affect his level of adjustment?
4. Finally, what are the implications of individuals attitudes for public snow control policies?

### Study Design

The study was conducted during two different seasons in one Canadian and six American cities. As in the other individual studies contained in this report, interview sites were chosen to reflect regional differences in average annual snowfall in order to determine if differing amounts affect an individual's perception of and adjustment to snow (Table 7-1): In the sample, two cities had low, two moderate, and two high average annual snowfall.

Telephone interviews for the study were conducted during the summer of 1969 on subjects selected at random from metropolitan telephone books.1/ Mail questionnaires were sent to the same subjects the following March to measure if an individual's evaluation of snow in urban areas differed significantly by season. Of the 303 interviews completed during the summer of 1969, only 20 per cent responded to the mail questionaire in March. The response varied, however, among the six cities. In the two cities with the lowest amount of average annual snowfall the rate of response dropped to 12 per cent, but in Rockford with moderate average annual snowfall, 34 per cent was registered.

The two questionnaires were not exactly the same; however, in order to measure any attitude change, the March questionnaire did include several questions from the August questionnaire.

Table 7-1

Number of Responses in Study Sites

| City | Season | | Average Annual Snowfall |
|---|---|---|---|
| | Summer | Winter* | |
| Evansville, Ind. | 54 | 7 | 14.4 |
| Nashville, Tenn. | 50 | 6 | 9.0 |
| Rockford, Ill. | 47 | 16 | 31.7 |
| Canton, Ohio | 51 | 10 | 38.7 |
| Utica, New York | 52 | 10 | ---- |
| Worcester, Mass. | 49 | 14 | 60.0 |
| Total | 303 | 63 | |

*While winter questionnaires were sent to all persons interviewed during the summer, the smaller number of winter informants reflects the actual number of returns.

**Climatological Data, U.S. Weather Bureau

Attitudes and the Snow Environment

Whether an individual perceives snow as a positive aspect of his environment is influenced by the characteristics of his snow environment.

1/ See Appendix A for a tabulation of socioeconomic characteristics of the subjects.

A definite pattern is apparent from analysis of our data. A majority of those interviewed in Evansville (55%) and Nashville (68%) indicated that they enjoyed heavy snowfalls in their city, while those in cities with heavier average annual falls perceived snow as either a nuisance or a serious inconvenience (Table 7-2).

In the two cities that experience heavy snows each year, Utica and Worcester, the respondents not only did not find a heavy snowfall enjoyable but considered such an event to be a serious inconvenience. Hence, the general pattern that emerges is that people in areas of light snowfall tended to regard a heavy snowfall favorably, respondents in areas of moderate snowfall were more or less divided, and most respondents in heavy snow regions viewed snow with disfavor.

Although these attitudinal responses are based upon a small number of interviews, the pattern that emerges complements the findings of earlier research on the perception and human adjustment to natural hazards. In areas where the frequency of hazard occurrence is high, Burton and his collegues found a large number of adoptions being made by a high proportion of the population. And, in areas where the occurrence of the hazard is low, few adoptions are made by few people. Moreover, "...wide variations are also to be expected in the proportion of population from place to place making any particular adjustment".1/

With this construct in mind, in the summer survey, respondents were asked whether more, less, or the same amount of snow was preferred in their area. Again, in the cities where snowfall is relatively low and infrequent,

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1/ Ian Burton, et al. "The Human Ecology of Extreme Geophysical Events." Natural Hazard Research, Working Paper No. 1, Dept. of Geography, Univ. of Toronto, (1968), p. 19.

TABLE 7-2

Evaluative Attitudes Toward Snow

Summer

| City | Serious Inconvenience | | Nuisance | | Enjoyable | | No response | |
|---|---|---|---|---|---|---|---|---|
| | No. | % | No. | % | No. | % | No. | % |
| Evansville | 4 | 7 | 16 | 29 | 30 | 55 | 4 | 7 |
| Nashville | 7 | 14 | 9 | 18 | 34 | 68 | 0 | 0 |
| Rockford | 7 | 14 | 23 | 49 | 15 | 31 | 2 | 4 |
| Canton | 3 | 6 | 19 | 39 | 21 | 41 | 8 | 16 |
| Utica | 16 | 30 | 17 | 33 | 14 | 27 | 5 | 10 |
| Worcester | 10 | 20 | 20 | 40 | 17 | 34 | 2 | 4 |
| Regina | 16 | 16 | 40 | 41 | 21 | 21 | 21 | 21 |
| | 63 | | 144 | | 152 | | 42 | |

Winter

| City | Serious Inconvenience | | Nuisance | | Enjoyable | | No response | |
|---|---|---|---|---|---|---|---|---|
| | No. | % | No. | % | No. | % | No. | % |
| Evansville | 0 | 0 | 2 | 28 | 5 | 41 | 0 | 0 |
| Nashville | 1 | 16 | 0 | 0 | 3 | 50 | 2 | 33 |
| Rockford | 1 | 6 | 5 | 31 | 8 | 50 | 2 | 12 |
| Canton | 1 | 10 | 4 | 40 | 3 | 30 | 2 | 20 |
| Utica | 7 | 41 | 8 | 47 | 2 | 11 | 0 | 0 |
| Worcester | 5 | 35 | 6 | 42 | 3 | 21 | 0 | 0 |
| Regina | 17 | 26 | 19 | 29 | 24 | 37 | 5 | 8 |
| | 32 | | 44 | | 48 | | 11 | |

Chi-square results for frequency data

By cities
Observed $x^2 = 70.01$

$x^2$ .01 = 34.80 for df = 18.

By season
Observed $x^2 = 4.68$

$x^2$ .05 = 7.82 for df = 3.

a higher proportion (18%) than in any other place were either satisfied or wanted more snow during the winter; whereas, a majority of the respondents in Utica and Worcester opted for less snow (Table 2-3). Although there was some possibility that this question might be wrongly interpreted by respondents because of the word "Science", which might evoke saccreligious feelings (especially among those who believe snow is an act of God). However, only 10 per cent of the sample gave no response, and in the section for other responses to this question only eight respondents gave any reference to religion.

The consistency of responses between an individuals assessment of snow (Table 7-2) and his preference on type of snow environment (Table 7-3) was made using the Goodman and Kruskal coefficient of association1/, which is an ordinal measure of association and is interpreted much the same as Pearson's R. (Table 7-4) The consistency was found to be fairly high (G=-.60); thus, those respondents who perceive snow as a nuisance or a serious inconvenience prefer to have less snow, and those who consider snow as enjoyable prefer the same amount or more snowfall during the winter season.2/

Consequently, in areas of heavy snowfall, the general public may be more sensitive to snowfall and demand greater efficiency from the public effort of snow removal. And, in cities with moderate snowfall where evaluative attitudes toward snow are more divided, the formulation and implementation of public snow control programs may be equally difficult but for different reasons. In addition, the seasonality of snowfall has been suggested as a reason for the inability of many cities to enact

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1/ Linton C. Freeman, Elementary Applied Statistics: For Students in Behavioral Science, New York: John Wileyard Sons, Inc., 1965, pp. 79-88.

2/ Leonard Doob, "Tropical Weather and Attitude Surveys." Public Opinion Quarterly, Vol. 32(Fall 1968), pp. 423-430.

TABLE 7-3

If Science could somehow devise a method of controlling the amount of snow, would you like to see:

| City | Response | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | More | | Same | | Less | | No Response | |
| | No. | % | No. | % | No. | % | No. | % |
| Evansville | 10 | 18 | 29 | 53 | 11 | 20 | 4 | 7 |
| Nashville | 9 | 17 | 19 | 37 | 12 | 23 | 10 | 19 |
| Rockford | 6 | 12 | 21 | 44 | 19 | 40 | 1 | 2 |
| Canton | 5 | 9 | 17 | 33 | 22 | 43 | 7 | 13 |
| Utica | 3 | 5 | 18 | 34 | 29 | 55 | 2 | 3 |
| Worcester | 5 | 10 | 9 | 18 | 30 | 61 | 5 | 10 |
| Regina | 6 | 6 | 30 | 30 | 46 | 46 | 16 | 16 |
| | 44 | | 143 | | 169 | | 45 | |

Observed $x^2$ = 49.45

$x^2$ .01 = 34.80 for df = 18.

TABLE 7-4

Attitude toward Snow and Preference for Type of Snow Environment

| Attitude | Type of Snow Environment | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | More | | Same | | Less | | No Response | |
| | No. | % | No. | % | No. | % | No. | % |
| Serious Inconvenience | 2 | 3 | 18 | 28 | 35 | 55 | 8 | 12 |
| Nuisance | 6 | 4 | 36 | 25 | 91 | 63 | 11 | 7 |
| Enjoyable | 35 | 23 | 69 | 45 | 30 | 19 | 18 | 11 |
| No Response | 1 | 2 | 20 | 47 | 13 | 30 | 8 | 19 |
| | 44 | | 143 | | 169 | | 45 | |

policies directed toward the amelioration of urban snow problems such as the prohibition of off-street parking.

Seasonality and Attitude Change

To the laymen, a popular view is that a direct relationship exists between physical and mental states of well-being and the temperature of the atmosphere. Hence, one might expect a respondent to evaluate snow favorably during the scorching heat of an August day and express disdain for snow during the latter part of February.

Though the seasons change and the snow may drift, attitudes toward snow appear to be less flexible. In a study in Dar-es Salaam, Tanzania, and Nairabi, Kenja, Doob 1/, found no consistent changes in attitudes toward five *a priori* scales: temporal orientation, patriotism, government, conception of people, and the individual's own well-being. Respondent's were interviewed between two seasons, a pleasant and unpleasant season. In the present study, the respondents appear to maintain the same evaluative attitude toward snow in August and February.

Nevertheless, a shift in attitude change did appear between summer and winter in each of the cities, but the change was not consistent. In Regina, 21 per cent and Rockford, 31 per cent considered snow as enjoyable when queried in August; but, in February, 37 per cent of the same respondents in Regina perceived snow as enjoyable and 50 per cent of those in Rockford responded favorably.

In each of the other cities, the shift in attitude toward snow was in the opposite direction. That is, more respondents found snow enjoyable during August than during February.

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1/ Leonard Doob, "Tropical Weather and Attitude Surveys." *Public Opinion Quarterly*, 32 (Fall, 1968), pp. 423-430.

The factors accounting for the different shifts in attitude, though not consistent or statistically significant, are unknown. It may be that attitudes toward the snow environment may be a function of a person's more basic values or primitive belief system. 1/ Before this survey, we had virtually no information on public attitude toward snow, and if, it seems desirable, we pursue a better understanding of the determinants of these attitudes, attention must be focused upon the underlying values.

Nevertheless, an effort was made to identify the reasons accounting for a favorable or unfavorable evaluation of snow. A two-part question in the summer interview schedule asked what each thought was the worst thing and the best thing about snow (Table 5). Evansville, with a light amount of average annual snow, most clearly saw the worst thing about snow to be an unspecified, general hazard and secondly, ugliness. Nashville and Rockford were divided in their evaluation between a general, overall hazard, and specifically an impediment to travel. Canton, Utica, and Worcester most often emphasized the impediment to travel as the worst aspect. Residents of Regina were split in their opinions recognizing the impediment to travel, the hazard, and the ugliness resulting from city snow.

Although the results are somewhat mixed, a weak pattern in the data suggests that the less snow a city has, the more residents identify is as being generally hazardous, an unspecified, evaluative response; but, the more snow a city has, the difficulty in travel becomes the main consideration.

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2/ See Milton Rokeach, Beliefs, Attitudes, and Values: Theory of Organization and Change, San Francisco: Jossey Bass, Inc., 1970, especially pp. 1-23.

TABLE 7-5

The Worst Thing About Snow in the Wintertime (per cent by rows)

| City | Nothing | Impedes Travel | Hazard | Ugly | Impedes Normal Activity | Economic Disbenefit | Don't Know | Other | No Response |
|---|---|---|---|---|---|---|---|---|---|
| Evansville | 0 | 12 | 46 | 22 | 1 | 0 | 1 | 3 | 1 |
| Nashville | 9 | 25 | 29 | 7 | 3 | 3 | 1 | 17 | 5 |
| Rockford | 1 | 21 | 25 | 12 | 0 | 8 | 0 | 27 | 2 |
| Canton | 2 | 27 | 11 | 11 | 0 | 9 | 1 | 21 | 1 |
| Utica | 13 | 36 | 7 | 0 | 0 | 9 | 0 | 34 | 1 |
| Worcester | 9 | 38 | 10 | 4 | 2 | 14 | 0 | 22 | 0 |
| Regina | 8 | 32 | 25 | 26 | 0 | 4 | 3 | 0 | 2 |

The Best Thing About Snow in the Wintertime (per cent by rows)

| City | Nothing | Functional | Pleasure (Non-sports) | Healthy | Sports | Don't Know | Other | No Response |
|---|---|---|---|---|---|---|---|---|
| Evansville | 7 | 14 | 61 | 1 | 9 | 3 | 0 | 1 |
| Nashville | 5 | 25 | 45 | 1 | 3 | 1 | 1 | 9 |
| Rockford | 8 | 21 | 53 | 2 | 8 | 2 | 0 | 4 |
| Canton | 7 | 5 | 66 | 1 | 9 | 3 | 1 | 1 |
| Utica | 17 | 5 | 55 | 3 | 11 | 3 | 0 | 1 |
| Worcester | 12 | 8 | 63 | 6 | 10 | 0 | 0 | 0 |
| Regina | 4 | 19 | 39 | 1 | 24 | 1 | 6 | 4 |

Significantly, only a small percentage of people perceived snow related to an economic disbenefit. Except for Worcester, less than 10 per cent of the respondents considered snowfall to be an economic cost. One might speculate that any public plea for policy change in snow control programs would appear to not be founded upon economic criteria but rather upon perceived, potential or real, psychic losses. Witness, for example, the negative feelings toward snow expressed in the category of a general hazard, ugliness, or an impediment to the normal flow of traffic.

The perceived benefits of snow were ubiquitous for each of the cities. Only Nashville and Regina did not have a majority responding with the pleasurable aspects of snow (Table 5). And, nobody considered snow to have economic benefits although a small number did mention snow to be functional in nature, for example, by adding moisture to the natural environment. Commensurate with our other findings, only in Worcester and Utica, the two heavy snowfall cities, were a significantly larger percentage of respondents unable to identify anything good about snow.

In summary, the general attitudes of city residents toward snow in their urban environment vary with the snow environment but not by season. In cities with the least average annual snow, respondents held the most favorable attitudes toward snow. In low snow environments, snow was perceived more negatively; and, in the middle range respondents were divided, holding sharply different views toward snow. These individual evaluations did not markedly shift from Summer to Winter. In two cities, respondents valued snow more during winter than in summer; whereas, in the remainder of the cities, the shift in attitude toward snow was toward the negative in winter. Moreover, the worst aspects about snow were identified as an unspecified general hazard and transportation problems. But again, residents in areas of heavy snowfall were more articulate in identifying a negative characteristic of snow--a impediment to travel. And finally, few residents saw snow as the cause of an economic cost while most saw at least something pleasurable in a heavy snowfall. If those respondents did not have to travel to work on heavy snowfall days, would their attitudes change toward a more favorable evaluation? If the "snowfall" idea were implemented into public policy, the psychic losses now attributed to snow in urban areas might be greatly reduced. We will return to the implications of this alternative later.

Human Adjustment

The summer interview questionnaire contained a number of inquiries regarding the preparations people individually take both at home and in their cars to combat the snow hazard. In the following section, the data were analyzed for regional differences in preparedness, and the factors influencing these different individual strategies, such as income, and evaluative attitudes toward snow.

Among respondents who were car owners, the most common adjustment was the carrying of a windshield scraper (Table 6). Of the sample population, 86 per cent adopted this adjustment. Significantly, there were no differences in the percentage of people by region who made the adoption, nor were personal, evaluative feelings about snow related (Table 7).

The adjustment data was also broken down between suburban housewives and others because housewives represented 44 per cent of the sample population (Table 8). While a majority of both groups carried windshield scrapers, the percentages were found to be significantly different, with the housewives more likely to have them.

TABLE 7-6

Individual Adjustments to Snow (%)

(Automobile)

| City | Shovel | | Scraper | | De-Ice Spray | | Sand | | Salt | | Snow Tires | | Chains | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No |
| Evansville | 25 | 72 | 83 | 14 | 37 | 61 | 3 | 94 | 11 | 87 | 40 | 55 | 14 | 83 |
| Nashville | 13 | 79 | 73 | 19 | 45 | 47 | 7 | 85 | 7 | 85 | 57 | 37 | 39 | 53 |
| Rockford | 51 | 48 | 78 | 21 | 29 | 70 | 29 | 70 | 21 | 78 | 65 | 34 | 12 | 87 |
| Canton | 19 | 80 | 86 | 13 | 43 | 56 | 17 | 82 | 19 | 80 | 78 | 21 | 17 | 82 |
| Utica | 21 | 78 | 78 | 21 | 46 | 53 | 26 | 71 | 26 | 73 | 75 | 23 | 15 | 84 |
| Worcester | 59 | 40 | 71 | 28 | 36 | 63 | 44 | 53 | 16 | 83 | 69 | 30 | 10 | 89 |
| Regina | 77 | 13 | 88 | 2 | 24 | 66 | 18 | 72 | 6 | 84 | 82 | 6 | 24 | 66 |

(Home)

| City | Snow Plow | | Salt | | Sled | | Skis | |
|---|---|---|---|---|---|---|---|---|
| | Yes | No | Yes | No | Yes | No | Yes | No |
| Evansville | 3 | 94 | 68 | 29 | 40 | 57 | 5 | 92 |
| Nashville | 3 | 89 | 47 | 45 | 39 | 53 | 7 | 85 |
| Rockford | 17 | 82 | 70 | 29 | 57 | 42 | 14 | 85 |
| Canton | 9 | 90 | 72 | 27 | 33 | 66 | 5 | 94 |
| Utica | 19 | 80 | 65 | 34 | 44 | 55 | 19 | 80 |
| Worcester | 20 | 79 | 44 | 55 | 38 | 61 | 18 | 81 |
| Regina | 5 | 87 | 11 | 81 | 50 | 42 | 13 | 79 |

*Row percentages do not add to 100 because of no responses and rounding errors.

TABLE 7-7

Attitude Toward Snow and the Adoption of Adjustments to Snow (%)

(Automobile)

| | Shovel | | Scraper | | De-Ice Spray | | Sand | | Salt | | Snow Tires | | Chains | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No |
| No Response | 57 | 38 | 78 | 16 | 21 | 73 | 21 | 73 | 9 | 85 | 69 | 23 | 23 | 71 |
| Inconvenience | 57 | 38 | 80 | 14 | 44 | 50 | 25 | 68 | 12 | 82 | 71 | 23 | 11 | 84 |
| Nuisance | 43 | 54 | 83 | 14 | 36 | 61 | 23 | 73 | 16 | 81 | 71 | 27 | 21 | 76 |
| Enjoyable | 31 | 65 | 80 | 16 | 36 | 60 | 15 | 80 | 14 | 82 | 65 | 29 | 21 | 75 |

(Home)

| | Snow Plow | | Salt | | Sled | | Skis | |
|---|---|---|---|---|---|---|---|---|
| | Yes | No | Yes | No | Yes | No | Yes | No |
| No Response | 7 | 88 | 30 | 64 | 42 | 52 | 16 | 78 |
| Inconvenience | 7 | 87 | 44 | 50 | 34 | 60 | 11 | 84 |
| Nuisance | 14 | 84 | 47 | 51 | 39 | 59 | 11 | 87 |
| Enjoyable | 8 | 88 | 57 | 38 | 52 | 44 | 11 | 84 |

*Row percentages do not add to 100 because of no responses and rounding errors.

TABLE 7-8

Suburban Housewife Adjustments to Snow (%)

(Automobile)

| | Shovel | | Scraper | | De-Ice Spray | | Sand | | Salt | | Snow Tires | | Chains | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No |
| Suburban Housewife | 51 | 49 | 95 | 5 | 44 | 56 | 28 | 72 | 20 | 80 | 82 | 18 | 24 | 76 |
| Other | 38 | 62 | 74 | 26 | 32 | 68 | 16 | 84 | 11 | 89 | 63 | 37 | 18 | 82 |

(Home)

| | Snow Plow | | Salt | | Sled | | Skis | |
|---|---|---|---|---|---|---|---|---|
| | Yes | No | Yes | No | Yes | No | Yes | No |
| Suburban Housewife | 11 | 89 | 57 | 43 | 48 | 52 | 14 | 86 |
| Other | 10 | 90 | 46 | 54 | 43 | 57 | 12 | 88 |

Observed $x^2$ = 30.285 for frequencies (not shown) of above data

$x^2_{.01}$ = 6.64 for df = 1.

TABLE 7-9

Per Capita Income and the Adoption of Adjustments to Snow (%)

(Automobile)

| | Shovel | | Scraper | | De-Ice Spray | | Sand | | Salt | | Snow Tires | | Chains | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No |
| \$ 0-\$ 5,000 | 32 | 62 | 62 | 32 | 23 | 72 | 13 | 81 | 12 | 83 | 52 | 42 | 16 | 79 |
| \$ 5,000-\$ 7,500 | 45 | 52 | 86 | 10 | 43 | 53 | 21 | 75 | 9 | 87 | 69 | 28 | 23 | 74 |
| \$ 7,500-\$10,000 | 46 | 53 | 94 | 5 | 37 | 62 | 18 | 81 | 21 | 78 | 78 | 20 | 18 | 81 |
| \$10,000-\$15,000 | 52 | 47 | 91 | 2 | 40 | 59 | 31 | 68 | 13 | 84 | 84 | 15 | 20 | 79 |
| over \$15,000 | 59 | 37 | 88 | 7 | 55 | 40 | 14 | 77 | 25 | 70 | 70 | 25 | 25 | 70 |

(Home)

| | Snow Plow | | Salt | | Sled | | Skis | |
|---|---|---|---|---|---|---|---|---|
| | Yes | No | Yes | No | Yes | No | Yes | No |
| \$ 0-\$ 5,000 | 7 | 87 | 47 | 48 | 31 | 63 | 7 | 87 |
| \$ 5,000-\$ 7,500 | 12 | 86 | 48 | 50 | 36 | 62 | 8 | 90 |
| \$ 7,500-\$10,000 | 3 | 96 | 56 | 43 | 58 | 41 | 15 | 84 |
| \$10,000-\$15,000 | 18 | 81 | 47 | 52 | 65 | 34 | 11 | 88 |
| over \$15,000 | 14 | 85 | 59 | 40 | 44 | 55 | 29 | 70 |

*Row percentages do not add to 100 because of no responses and rounding errors.

Observed $x^2$ = 43.33 for frequences (not shown) of above data
$x^2$ .01 = 15.09 for df = 5.

TABLE 7-10

Age and the Adoption of Adjustments to Snow (%)

(Automobile)

| Age | Shovel | | Scraper | | De-Ice Spray | | Sand | | Salt | | Snow Tires | | Chains | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes | No |
| 10-20 | 38 | 61 | 89 | 10 | 42 | 57 | 19 | 80 | 23 | 76 | 78 | 19 | 27 | 72 |
| 20-30 | 44 | 53 | 85 | 11 | 28 | 69 | 14 | 83 | 9 | 88 | 75 | 22 | 17 | 79 |
| 30-40 | 54 | 45 | 91 | 8 | 36 | 63 | 20 | 77 | 20 | 77 | 19 | 80 | 26 | 73 |
| 40-50 | 47 | 50 | 96 | 1 | 50 | 47 | 27 | 71 | 11 | 86 | 81 | 16 | 22 | 76 |
| 50-60 | 53 | 41 | 90 | 4 | 46 | 48 | 39 | 53 | 13 | 81 | 76 | 18 | 16 | 79 |
| 60-70 | 35 | 62 | 67 | 30 | 35 | 62 | 14 | 83 | 10 | 87 | 53 | 46 | 12 | 85 |
| over 70 | 13 | 75 | 30 | 58 | 13 | 75 | 16 | 72 | 16 | 72 | 27 | 61 | 13 | 75 |

(Home)

| Age | Snow Plow | | Salt | | Sled | | Skis | |
|---|---|---|---|---|---|---|---|---|
| | Yes | No | Yes | No | Yes | No | Yes | No |
| 10-20 | 12 | 87 | 68 | 31 | 80 | 19 | 25 | 74 |
| 20-30 | 2 | 96 | 38 | 60 | 51 | 47 | 9 | 89 |
| 30-40 | 18 | 81 | 58 | 41 | 75 | 25 | 15 | 84 |
| 40-50 | 5 | 94 | 47 | 52 | 37 | 62 | 13 | 86 |
| 50-60 | 13 | 81 | 62 | 32 | 30 | 65 | 11 | 83 |
| 60-70 | 17 | 80 | 39 | 58 | 8 | 89 | 5 | 92 |
| over 70 | 5 | 83 | 41 | 47 | 5 | 83 | 5 | 83 |

*Row percentages do not add to 100 because of no responses and rounding errors.

Similarly, when respondents were grouped by income, there was no statistically significant relationship between the adoption of windshield scrapers and income class (Table 9). However, a difference did appear when city residents were grouped according to age - those over 60 were the only group with a majority not having windshield scrapers (Table 10), and the only in which age was statistically significantly related to the adoption of adjustment.1/

Each adjustment listed, whether for the home or car, (Tables 6-10) can similarly be reviewed. In general, human adjustment to the snow hazard appears to be rather ubiquitous. It appears that only the liklihood of having snow tires varies by region - expectedly heavy snow cities having them more often (Table 6). But, the liklihood of carrying a shovel in the car appears to vary with personal attitudes toward snow (Table 7).

Public Opinion on Snow Control Measures.

> "Only God Helps the little side streets get plowed."
> Worcester

> "...but since snow doesn't bother me, I don't pay much attention to forecasts."
> Regina

There are two public forces in a city which are charged with helping the residents cope with snow hazards; the city government and the weather bureau. Both perform their function with varying degrees of efficiency - as viewed by people in the cities. This last part of the study is concerned with public opinion on the usefulness of snow control measures to them.

One objective in the summer interview was to determine if people thought the snow removal efforts of their city were adequate. Based upon the summer interview data, we find that residents have difficulty

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1/ $x^2 = 85.24$ sig. at .01 level.

in realistically evaluating the overall snow removal program. Concerning all interviewees, nearly one-third of the respondents (32%) gave no response concerning the adequacy of the municipal snow removal program. These answers indicate that is was difficult for people to comprehend the amounts of money named by the interviewers when making a judgment about the efficiency of the program. We find that few people are aware of the percentage of their city's budget expended upon snow control; indeed, few people were aware of what may constitute good fiscal policy for snow control. Only in Regina and Worcester were other opinions (too much or too little) expressed by more than 40 per cent of the respondents.

When the question of public expenditure and quality of snow control were cross-tabulated with personal attitudes to snow (Table 2), a weak relationship appears to emerge. Those respondents finding snow to be a serious inconvenience were the most likely to reply "too little" - an answer consistent with their feelings, (Table 11). Otherwise, here too, no strong pattern emerges.

<u>Summary</u>.

Part of the study of any natural hazard is determining how people who are affected by it deal with the hazard. City residents are afflicted by snow every year; residents in six American cities and one Canandian city were interviewed in this study to obtain a cross-section of public opinion on snow, on individual adjustments to snow, and on public snow control measures.

Personal attitudes toward snow varied by city - cities with the least snowfall were likely to judge snow to be enjoyable; those with the most were likely to judge it a serious inconvenience. While the hazard of snow

TABLE 7-11

Your city government now spends $ (amount appropriate for each city) on snow removal; considering the job they do, do you think this is: (percentage by rows)

| By City | Too Much | Too Little | Just About Right | No Response |
|---|---|---|---|---|
| Evansville | 25 | 3 | 37 | 33 |
| Nashville | 9 | 15 | 47 | 25 |
| Rockford | 12 | 8 | 42 | 36 |
| Canton | 9 | 1 | 41 | 47 |
| Utica | 17 | 17 | 38 | 26 |
| Worcester | 26 | 14 | 26 | 30 |
| Regina | 19 | 27 | 31 | 21 |

| By Personal Feelings | Too Much | Too Little | Just About Right | No Response |
|---|---|---|---|---|
| Serious Inconvenience | 22 | 31 | 17 | 28 |
| Nuisance | 16 | 12 | 40 | 30 |
| Enjoyable | 17 | 9 | 40 | 30 |
| No Response | 14 | 11 | 42 | 30 |

or the impediment to travel it causes were often cited as problems, city residents were not functionally able to judge value-received on city expenditures for snow control measures. Nor did a definite opinion emerge for or against more snow control measures. Of all the residents interviewed, the suburban housewives were best prepared, but even with this group the level of adjustment is less than the practical possible.

The notion of declaring a snow-fest or snow-day in cities where the amount and rate of fall greatly exceed the removal capacity may be an economically viable alternative, but an unpopular one among society. Yet, to urban man who steadily increases his tempo in life, a spontaneous holiday could clearly contribute to his mental and physical well-being.

From our winter mail survey, only 11 per cent favored the implementation of the snow-day idea, while 63 per cent favored an improvement in the public snow program, form the purchase of more technology to the restriction of off-street parking. The reasons for the unfavorable response for a snow-day(s) are speculative; however, the probability of acceptance would appear rather low.

One might hypothesize that the adoption of the snow-day is a form of behavior that is incongruent with a person's basic or primitive values. To a populace where the underlying value-orientation is that of man as dominant over nature, a snow-day policy would signify defeat. Clearly, an increase in the public snow control effort would enhance a man over nature view. Or, and possibly commensurately, might be the existence of an underlying value of high achievement -- again, the policy of a snow-day could be incongruent with such a value.

In any event, before the social engineering approach can be applied to changes in public policy of the urban snow problem, more research into public attitudes need to be undertaken, especially commensurate with detailed economic analyses within a particular city.

# APPENDIX A

## Socioeconomic Characteristics of the Respondents

### I. Dwelling

| | House | Apartment | No Response |
|---|---|---|---|
| Evansville | 46 | 5 | 3 |
| Nashville | 39 | 8 | 3 |
| Rockford | 40 | 7 | 0 |
| Canton | 46 | 4 | 1 |
| Utica | 43 | 8 | 1 |
| Worcester | 34 | 14 | 1 |
| Regina | 86 | 11 | 1 |
| Total | 334 | 57 | 10 |

### II. Ages

| | 10-20 | 20-30 | 30-40 | 40-50 | 50-60 | 60-70 | over 70 | No Response |
|---|---|---|---|---|---|---|---|---|
| Evansville | 6 | 14 | 7 | 8 | 3 | 11 | 4 | 1 |
| Nashville | 11 | 10 | 10 | 4 | 2 | 6 | 5 | 2 |
| Rockford | 8 | 8 | 13 | 6 | 2 | 4 | 6 | 0 |
| Canton | 2 | 4 | 8 | 14 | 8 | 11 | 4 | 0 |
| Utica | 8 | 7 | 7 | 8 | 7 | 9 | 6 | 0 |
| Worcester | 4 | 9 | 5 | 5 | 9 | 11 | 6 | 0 |
| Regina | 8 | 32 | 22 | 14 | 12 | 4 | 5 | 1 |
| Total | 47 | 84 | 72 | 59 | 43 | 56 | 36 | 4 |

### III. Income

| | $0-$5,000 | $5,000-$7,500 | $7,500-$10,000 | $10,000-$15,000 | over $15,000 | N.R. |
|---|---|---|---|---|---|---|
| Evansville | 23 | 9 | 10 | 4 | 3 | 5 |
| Nashville | 17 | 9 | 7 | 4 | 3 | 9 |
| Rockford | 15 | 3 | 13 | 12 | 4 | 0 |
| Canton | 13 | 10 | 18 | 5 | 5 | 0 |
| Utica | 13 | 15 | 8 | 4 | 3 | 9 |
| Worcester | 13 | 8 | 6 | 6 | 4 | 12 |
| Regina | 22 | 68 | 17 | 9 | 5 | 17 |
| Total | 116 | 82 | 79 | 44 | 27 | 52 |

APPENDIX A
continued

IV. Sex

| | Male | Female | No Response |
|---|---|---|---|
| Evansville | 10 | 43 | 1 |
| Nashville | 10 | 38 | 2 |
| Rockford | 12 | 34 | 1 |
| Canton | 12 | 39 | 0 |
| Utica | 7 | 44 | 1 |
| Worcester | 11 | 37 | 1 |
| Regina | 37 | 59 | 2 |
| Total | 99 | 294 | 8 |

V. Marital Status

| | Single | Married | Widowed | Divorced | No Response |
|---|---|---|---|---|---|
| Evansville | 13 | 30 | 8 | 2 | 1 |
| Nashville | 15 | 31 | 2 | 0 | 2 |
| Rockford | 11 | 32 | 4 | 0 | 0 |
| Canton | 4 | 41 | 5 | 0 | 1 |
| Utica | 13 | 35 | 4 | 0 | 0 |
| Worcester | 9 | 35 | 4 | 0 | 1 |
| Regina | 19 | 79 | 4 | 0 | 0 |
| Total | 84 | 283 | 27 | 2 | 5 |

# CHAPTER 8

## CONCLUSION

Clifford Russel and Duane D. Baumann

In this report, we have attempted to show how general techniques developed in studying such dramatic natural hazards as flood and drought may be applied to the more work-a-day problem of urban snowfalls, with a view to assisting municipalities in coping more efficiently. To this end, we have set out a framework focusing on the adjustments possible in the face of an uncertain nature; the costs of these adjustments; and their impact on damages actually suffered when the anticipated events occur. We stressed that the multidimensional character of urban snowfalls (for example, the importance of rate of fall, wind speed, temperature and time of day) made any application of the adjustment model potentially an extremely complex task. And in our example we concentrated entirely on the rate of fall dimension. We also pointed out that the range of available adjustments to snowfall involved decisions on several different time horizons; from the relatively long run, over which the size and composition of the stock of snow-fighting equipment is chosen; to the very short run in which mobilizations are ordered to meet threatened storms, or in which projected accumulations are used in deciding what method to use in fighting a storm going on at the moment. Our study is of necessity limited to longer-run questions, but, as we point out below, research into the short run, using already developed methods, promises significant returns.

Two basic threads were developed withing the framework and limitations we thus set for ourselves. One concerned the actual application of the optimal-adjustment model to the choice of the "best" long-run choice by municipal governments of snow removal capacities. This application rested on estimates of damages due to traffic disruption caused by snowfalls, and on estimates of the costs of maintaining particular snow "removal" capabilities. The damages were based on a study published by the American Public Works Association, and the costs were pieced together from our interview data and information found in the public-works literature. This analysis was considered illustrative, and no particular interest attaches to the numbers derived for "optimal" removal capabilities. It does seem clear, however, that considerbly more valuable results could be achieved with a relatively modest effort aimed at defining and finding accurate costs for "removal capabilities" for use with existing models of traffic-disruption damage. Further, and probably considerably more difficult research might be undertaken to improve these latter models themselves. It would be particularly valuable if this research looked at alternative assumptions about the extent to which an attempt is made to maintain normal traffic movement, since one of the most appealing potential adjustments is the "snow-day", the closing of non-essential public and private operations. This reduces the pressure for instant snow removal and allows time for enjoyment of the positive aspects of urban snowfalls.

Another potentially important research problem is the short-run situation in which decisions must be made on the basis of forecasts at the beginning and end of a specific storm. The tools for dealing with this problem have been developed and applied in other weather-forecast situations. (Examples are cited in the text.) But their application would involve considerable difficulty because almost nothing is known about either the costs and benefits involved or the relevant probability distributions. Thus, it is necessary to know the probabilistic relation between forecast and actual event; and at a minimum three dimensions of the individual storm are of interest: onset, rate of fall, and length of storm. (We originally intended to do such a study in at least one or two of our sample cities, but it became obvious that the task of gathering a sufficiently large number of observations of forecast and actual event in each of these dimensions was going to prove far too expensive and time-consuming to fit within our already strained limits.) The aim of such a study might very well be the development of rules of thumb for the use of responsible municipal officials in deciding what actions to take under what Weather Bureau forecasts.

The second major thread developed in the present study has been the attitudes toward and adjustments to urban snowstorms on the part of other municipal decision units; in particular, retail shops, industrial establishments and private individuals. Across all these units we found a striking, but hardly surprising tendency to rely almost exclusively on the public sector for adjustments. Thus, businesses relied on municipal snow removal actions to allow them to operate at approximately normal levels on storm days, with only small expenditures for parking lot or sidewalk clearance. The thought of closing down to take some pressure off the city street system was not considered.1/ Perhaps more surprising

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1/ There is a very good reason for no individual firm considering closing down; it would assume that its competitiors would reap the benifits of the less disrupted traffic by staying open to produce or sell. This is simply an example of the free-fider problem.

is the extent to which we found that individuals place all their trust in public snow removal and don't bother to carry shovels, sand, or other emergency aids in their cars. About the only traffic-related adjustment the individual is required to make is that of snow tire use in most northern cities; and the only one he voluntarily adopts on a very wide scale is the carrying of a windshield ice-scraper.

Clearly, the choice of private adjustments and the heavy reliance on public actions to deal with urban snowfalls must reflect individual attitudes toward snow and snowstorms. In this area, our study found that individuals tended to view snow more negatively and snowstorms more specifically as threats to their mobility with an increase in the average annual snowfall also called forth a larger number of individual adjustments. This finding accords with observations of response to flood hazard reported by Kates.2/

As we have emphasized, the results of this study are not so directly useful to muncipal officials as we would wish. The problems of data collection and manipulation proved more difficult and time-consuming than anticipated. But the study does indicate a method for use in informing municipal decisions concerning what is, in the northern tier of states, an expensive public service. In present circumstances of local financial stringency, it may well seem worthwhile to pursue this approach further. At least such research would indicate to what extent municipalities

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1/ There is a very good reason for no individual firm considering closing down; it would assume that its competitors would reap the benefits of the less disrupted traffic by staying open to produce or sell. This is simply an example of the free-rider problem.

2/ R. W. Kates, Hazard and Choice Perception in Flood Plain Management, Department of Geography Research Paper #78 (Chicago: University of Chicago, 1962).

are over- or under-adjusted, given their intention of following the traditional path of public snow removal, designed to allow a normal, or nearly normal, flow of traffic. More generally, such a study would go beyond our work on private-sector adjustments and look at possibilities for shifting some of the burden from public to private hands by, for example, the more liberal application of the "snow-day." For such an expended effort, this study can serve as a guide to empirical and conceptual problems.