

# PLANNING AIRPORT SNOW AND ICE REMOVAL USING OPERATIONS RESEARCH TECHNIQUES

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## ABRIDGMENT

•THE work described in this paper was carried out by a team of equipment engineers and operations research specialists. The analysis began in mid-1969 and was completed in December 1970.

The terms of reference for the study were established by the Federal Aviation Administration in 1967. Essentially, they called for an analytic approach that would "...describe and define in quantitative form, those factors which affect the design and

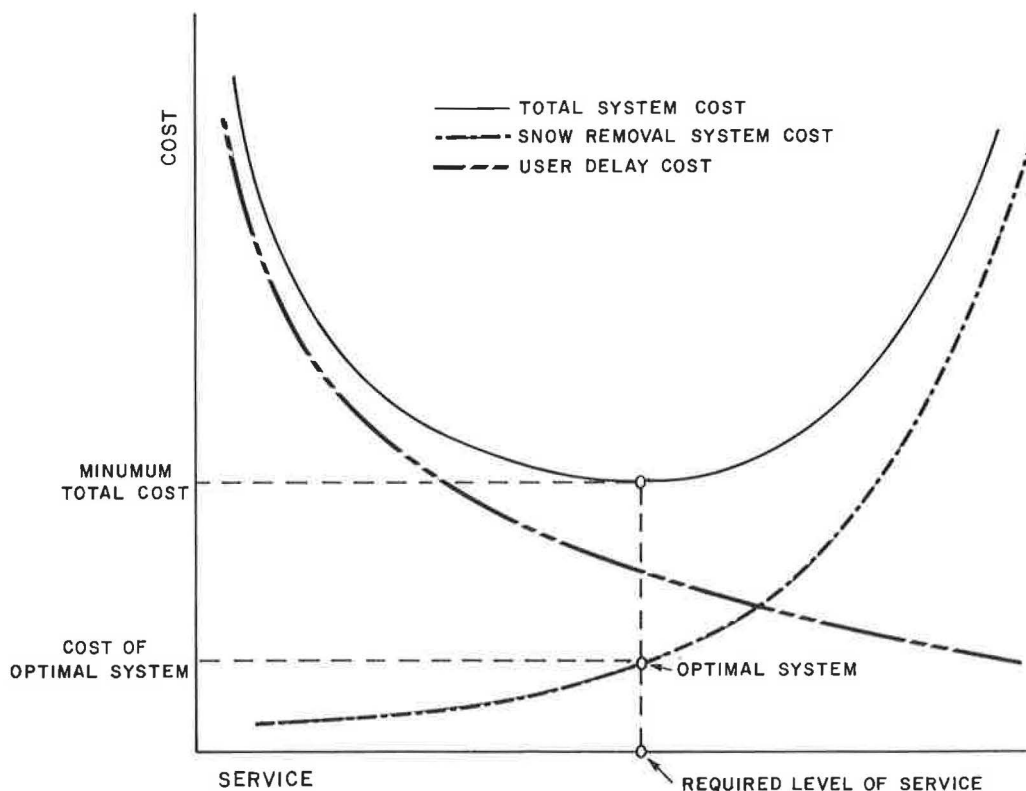


Figure 1. The choice of snow removal system based on minimum total cost.

use of systems for removal of snow, ice, slush and standing water from civil airport surfaces. These descriptions and definitions should treat in detail removal system characteristics, specify critical or limiting factors of these systems, and the influence which the various physical operational and environmental factors have on system design. The systems should be applicable to all U.S. airports...."

The objective as stated is rather diffuse. Expressed more simply, the study attempted to answer two questions:

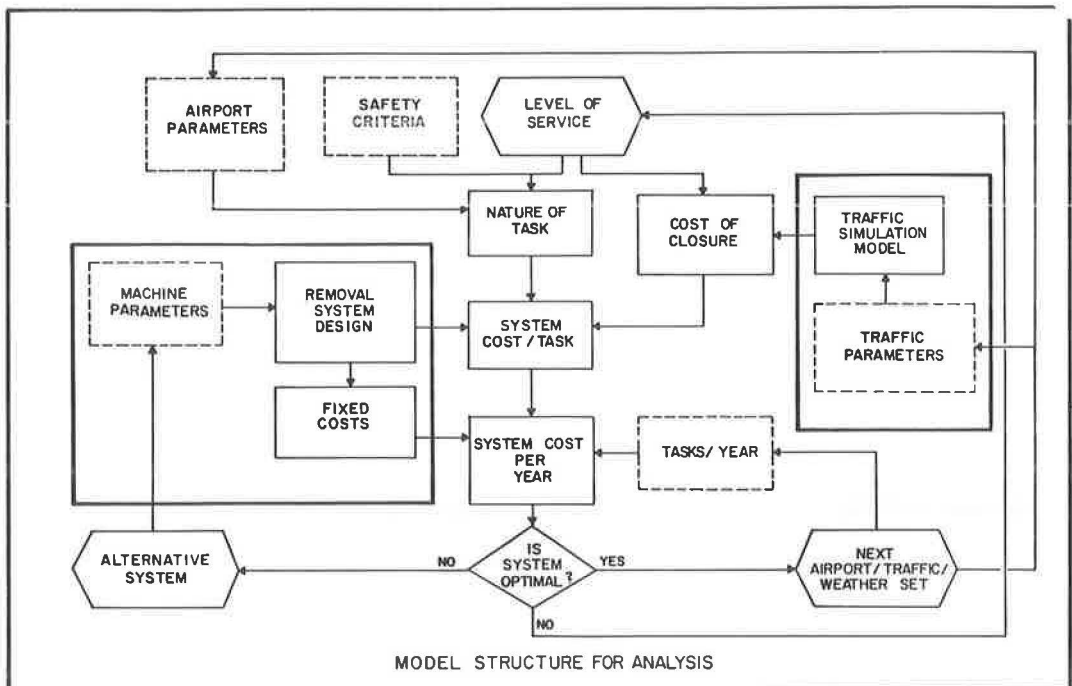
1. What level of service is an airport economically justified in giving to users?
2. What equipment and methods will give the best value for this money?

### THE SNOW REMOVAL PROBLEM

It takes an investment in equipment and expenditures on labor and machine operation to make a runway safe during a snowstorm. Shortening the runway clearance interval will result in increasing costs of removal. The interruption of air traffic operations for clearance will result in user costs incurred through delays, diversions, and cancellations; however, these decrease as the interval shortens. Figure 1 shows the general variation in cost. It may be reasonably assumed that the optimum service level is that for which the total costs to airport and users is a minimum. The problem therefore is to choose the system that will ensure a minimum total cost for each airport type, level of traffic, and annual snowfall.

### THE APPROACH

The objective of the general model was to calculate the total annual costs resulting from the use of snow removal systems of varying effectiveness—i. e., requiring vary-



Note: 1) Heavy lines enclose each model.  
 2) Dotted lines enclose inputs.  
 3) Other boxes show calculation.

Figure 2. An outline of the modeling approach to removal system planning.

ing intervals of time to accomplish a clearance operation (Fig. 2). This calculation in turn required (a) the design of alternative snow removal systems (Table 1) and (b) a traffic simulation model to allow evaluation of user costs resulting from different periods of runway closure (Fig. 3). By using the basic cost information provided by these submodels and taking into account the annual level of snowfall, the general model projected annual costs (Figs. 4 and 5).

To permit the use of meaningful generalizations about most real-life airport situations, a relatively large number of alternative combinations of airport, traffic, snow-

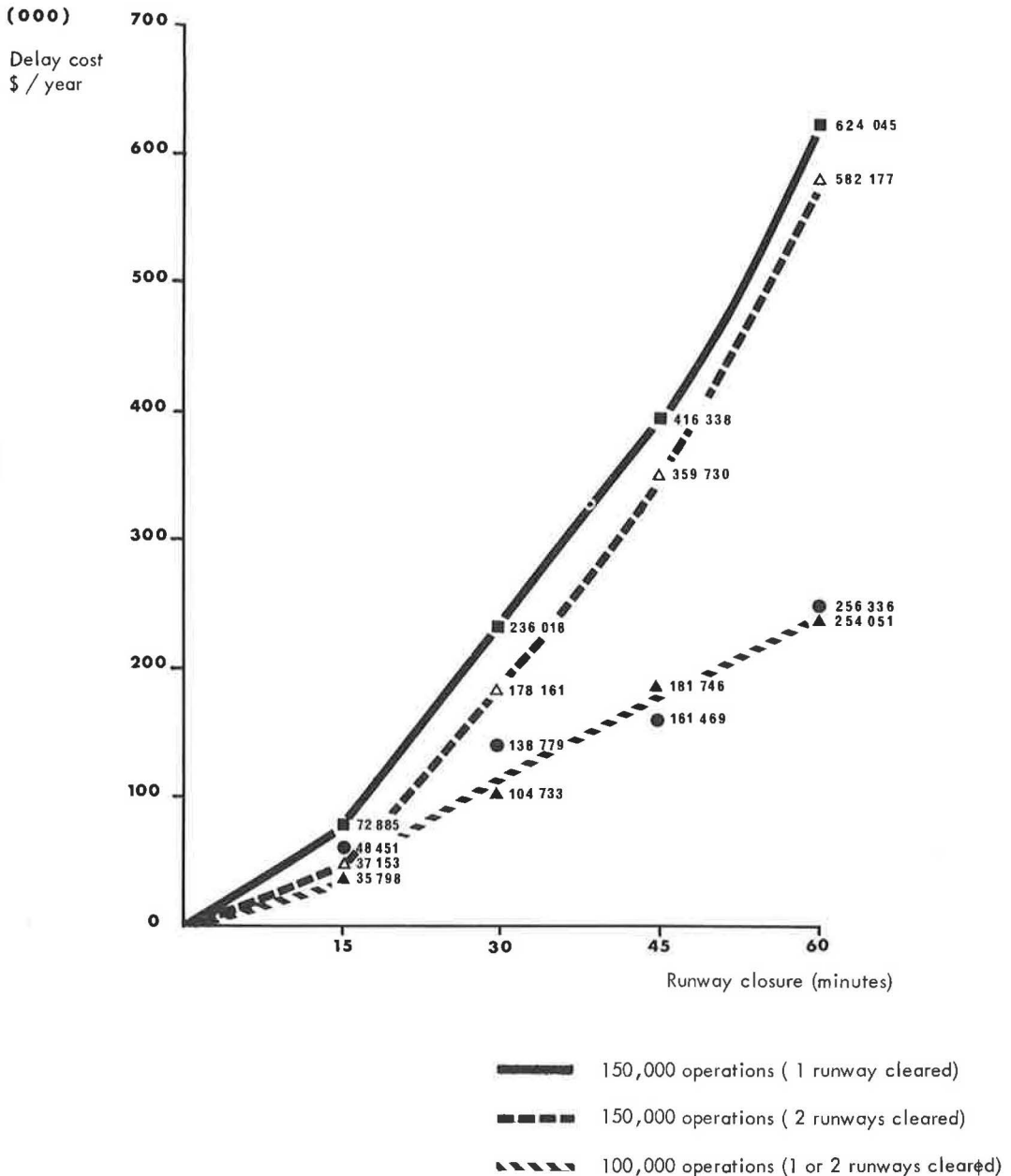
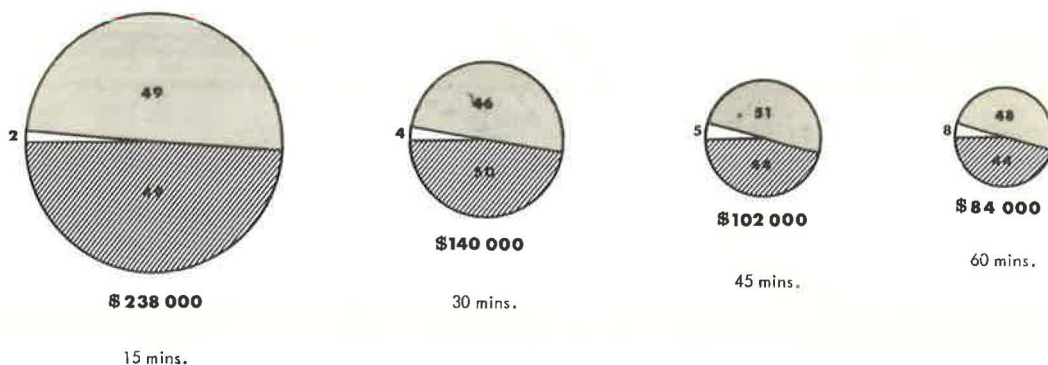


Figure 3. Annual delay costs incurred for different runway closure policies for snow removal on a type 4 airport.

TABLE 1  
ALTERNATIVE EQUIPMENT PACKAGES FOR USE ON TYPE 4 AIRPORT

Clearance Time (Min)	No. of Units	Equipment Type	Capital Cost (\$)	No. of Men
15	8	Sweeper	853,800	28
	10	4 x 2 plow		
	5	30-ft plow		
	3	High-speed blower		
	1	30-ft plow		
	1	Blower (small)		
30	4	Sweeper	497,500	15
	5	4 x 2 plow		
	4	30-ft plow		
	2	High-speed blower		
45	4	Sweeper	329,200	12
	4	4 X 2 plow		
	1	30-ft plow		
	1	High-speed blower		
	1	4 x 4 plow and wing		
	1	Blower (small)		
60	4	Sweeper	272,700	9
	3	4 x 2 plow		
	1	30-ft plow		
	1	High-speed blower		
75	2	Sweeper	231,500	6
	1	4 x 2 plow		
	2	30-ft plow		
	1	High-speed blower		

fall, and level-of-effectiveness were evaluated by using these models. Seven airport types were assumed. Levels of traffic ranged from 10,000 itinerant annual operations, of which 95 percent were assumed to be general aviation, to more than 400,000 with less than 10 percent general aviation content. Annual snowfall ranged from 25 to 125 in., and levels of effectiveness ranged from 15 min to 3 hours. Table 1 and Figures 3 through 5 provide an example of the process for one combination only.



Annual snow removal costs predicted for a Type 4 Airport in a 50" snowfall region and with about 100,000 operations per year.

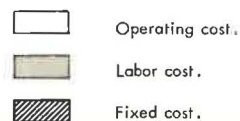
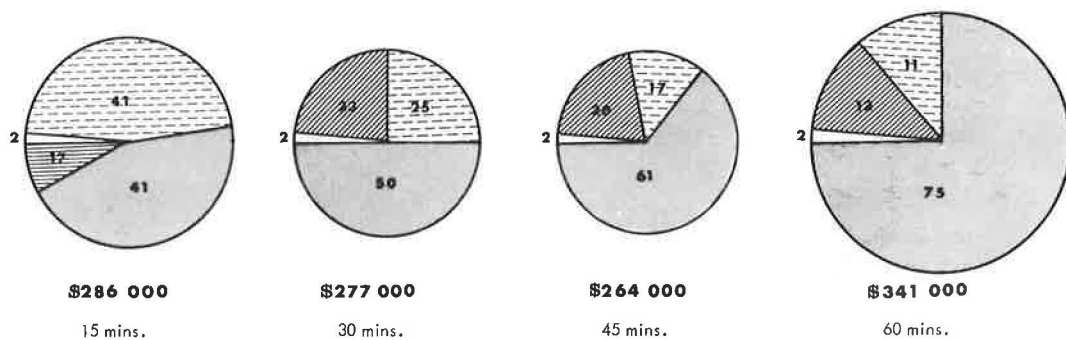


Figure 4. Magnitude and allocation of removal system cost for varying runway clearance intervals.



Total System Cost predicted for a Type 4 Airport in a 50 " snowfall region and with around 100,000 operations per year.

Note: Numbers within segments denote percentages of total cost.

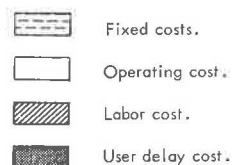


Figure 5. Magnitude and allocation of total cost for varying runway clearance intervals.

## RESULTS OF THE STUDY

As stated previously, the study attempted to answer two questions. The first, regarding level of service, is answered by means of the diagram shown in Figure 6. By referring to this diagram the decision-maker is able to choose the service level appropriate for his airport layout, annual snowfall, and traffic intensity. The second question, concerning how this level can be achieved, is answered by reference to a diagram

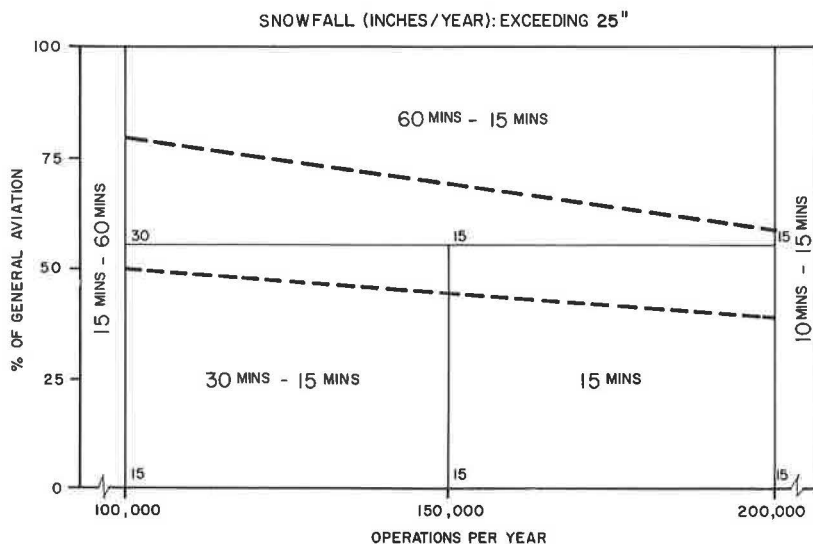


Figure 6. Runway clearance interval as a function of snowfall and traffic.

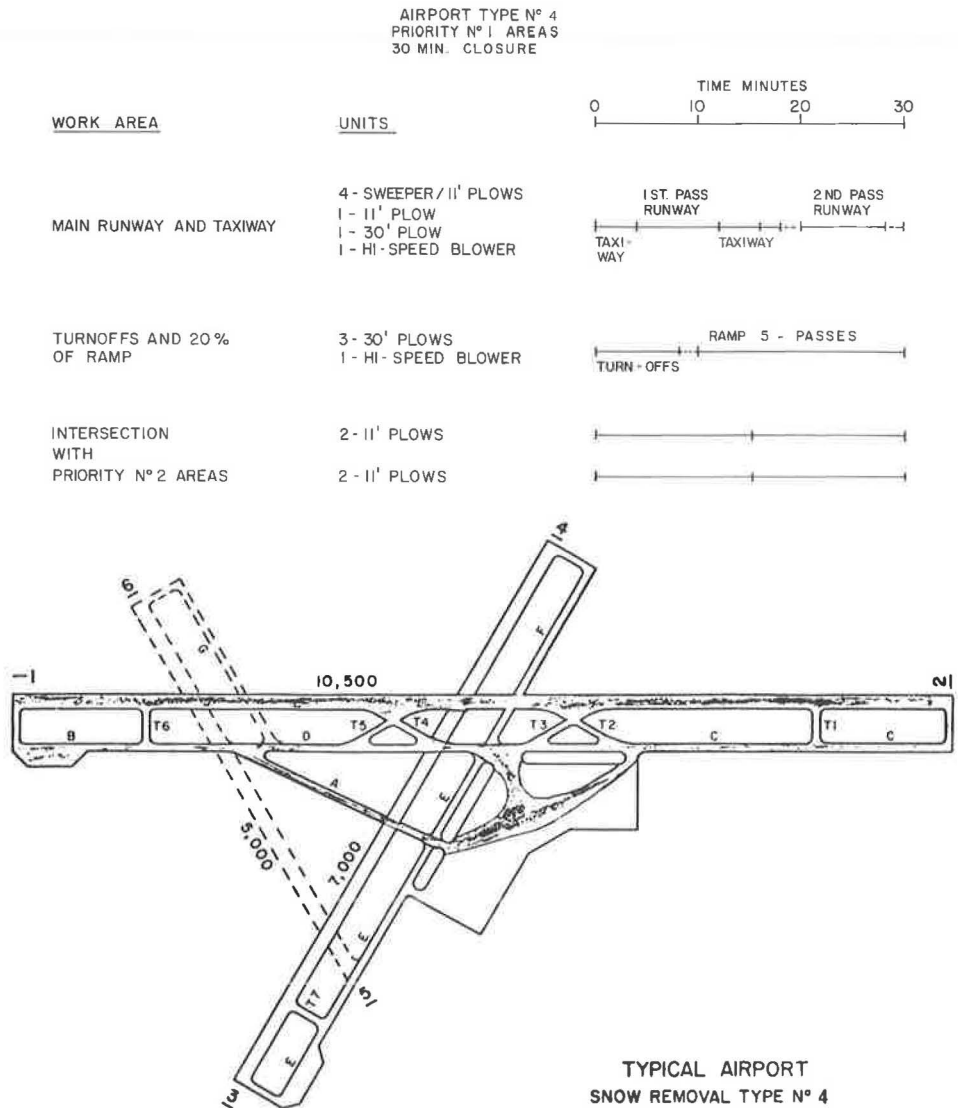


Figure 7. Equipment deployment for main clearance.

such as that shown in Figure 7, which is provided in conjunction with detailed equipment package and labor requirement specifications.

### CONCLUSION

Although the study was concerned purely with airport snow removal, some parallels with the problem of snow clearance from roads or bridges may be inferred. Whether the problem area is an urban street network, a turnpike, or a bridge, the quality of snow or ice control must be based on consideration of benefits accruing to road users or the region as well as system cost. The approach to be taken, similar in its essentials, would probably comprise the following steps:

1. Derive clearance priorities for subareas or links within the road network;

2. Determine levels of service (speed of response and completeness of removal) for each link; and

3. Design removal systems, i.e., specification of types and numbers of machines, de-icing compounds, and men together with methods of deploying them for maximum effectiveness.

Where the snow and ice control task is carried out by subcontractors, the approach would generate (a) standard procedures for snow removal and ice control by subarea or link; (b) required equipment types, numbers, and manpower in each subarea; (c) required minimum performance for each subcontractor; and (d) a cost structure based on geographical area, required performance, and snowfall to allow a fair contract price to be set.

#### ACKNOWLEDGMENT

The study described in this paper was carried out jointly with Hovey and Associates Ltd., Ottawa, under contract with the Federal Aviation Administration System Research and Development Service. A final report containing study conclusions is available from the National Technical Information Service, Springfield, Virginia.