Combatting Ice on Airtrans and Other Guideways

Robert J. Patton and Roland R. Raven, Vought Corporation, Dallas, Texas

The AIRTRANS transportation system at the Dallas/Fort Worth Airport, manufactured by the Vought Corporation, is fully automated and transports people and cargo throughout the airport complex. The AIRTRANS system uses 13 miles of guideway with 68 vehicles to interconnect 4 terminals, 2 remote parking lots, a hotel and the maintenance areas. The AIRTRANS system operates 24 hours a day, 7 days a week and has accumulated a total of 14 million vehicle miles since the opening of the airport in 1974. The system was designed specifically for the climatic environment of the Dallas/Fort Worth, Texas area. The original plan for operation during the infrequent periods of severe weather was that the constant vehicle movements throughout the system would keep the guideway and wayside system clear of ice and snow. This procedure proved completely inadequate and has resulted in system shutdown during periods of severe ice and snow. Buses and trucks are used during these periods to provide movement of people and cargo. This paper describes the approach the Vought Corporation undertook to combat the AIRTRANS environmental problems. The proposed improvements were considered too costly for the few days of severe weather and resulted in backup bus service at onset of icing weather. It is essential that for site specific applications, a Systems Engineering approach be utilized in order to match performance requirements with cost effective methods. Finally, a full scale demonstration is required to validate the selected approach.

Introduction to AIRTRANS

The AIRTRANS transportation system of the Dallas/Fort Worth Airport (Figure 1) was designed to transport people and cargo throughout the airport complex safely and automatically. The 4 terminals, 2 remote parking lots, hotel, and maintenance areas are interconnected by AIRTRANS, using 13 miles of guideway (Figure 2) with 51 people vehicles and 17 cargo vehicles. The vehicles (Figure 3) travel over the guideway on a series of dedicated routes, 5 for passengers, 4 for employees and 3 for cargo. The routes overlay each other forming a complex network. Over 24,000 switch operations and 9,000 station stops per day occur throughout the system. The vehicles stay on their individual routes taking the proper direction at switches, unless rerouted by the central control operator.

The AIRTRANS system employs sophisticated computers and other electronic equipment to provide operational efficiency and flexibility; however, the operational safety of the AIRTRANS system depends on the high reliability railroad relays and hard wiring in the vehicles and wayside electronic units. A traditional fail-safe approach to automatic signalling, proven by decades of service in the railroad industry, has been adapted for AIRTRANS. Failures of individual relays, modules, computers, power supplies, pneumatic systems, etc., may stop the operation of a single train or the entire system, but, in all predictable circumstances, every vehicle is fully protected from collision with other vehicles. If central control or any other element of the supervisory system fails, vehicle operation will continue safely and automatically, though at a sub-optimum performance level.

The AIRTRANS system was designed specifically for operation at the Dallas/Fort Worth Airport and the climate of this area. Specification requirements included 0^{o} ambient temperature, operation in winds up to 65 mph and blowing snow; but not combined. Originally, it was assumed that frequent vehicle operation would keep the guideway system clear of ice and snow. This plan proved completely inadequate, and it was realized that additional steps would be required even for the Dallas/Fort Worth area. The onset of a "blue norther" with freezing rain has shut the entire system down within four (4) minutes or less.

AIRTRANS Vehicle Configuration

The AIRTRANS passenger vehicles (Figure 3) are designed to transport 40 passengers in an environment of comfort and quality comparable to aircraft travel. Upholstered seats, vertical handholds, a carpeted floor, heating and air conditioning, light level sufficient for reading, tinted windows, and ABS

FIGURE 1
D/FW AIRPORT
AT DALLAS/FORT WORTH, TEXAS

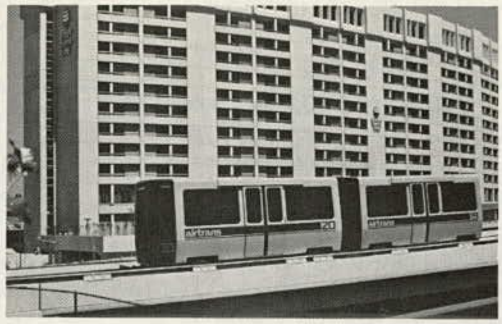


FIGURE 3
AIRTRANS VEHICLE
PASSING AIRPORT
MARINA HOTEL

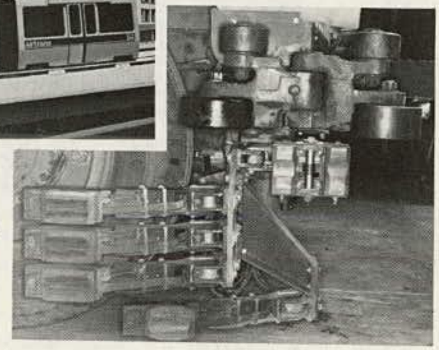


FIGURE 4
VEHICLE SIGNAL AND
POWER COLLECTION
SYSTEM

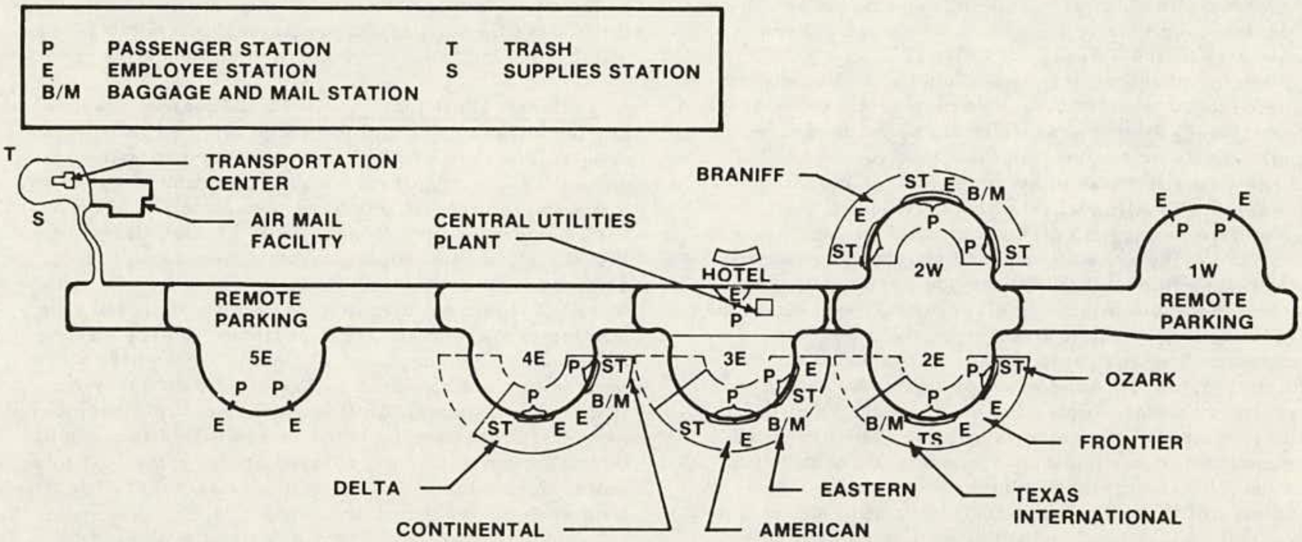


FIGURE 2
GUIDEWAY AND TERMINAL LAYOUT
AT D/FW AIRPORT

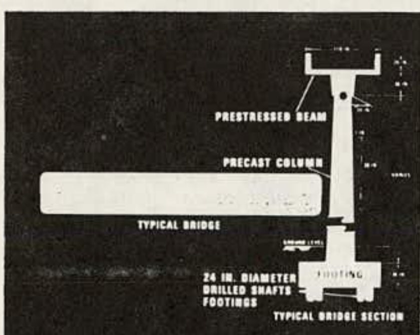


FIGURE 5
CROSS SECTION
OF AIRTRANS
ELEVATED
GUIDEWAY

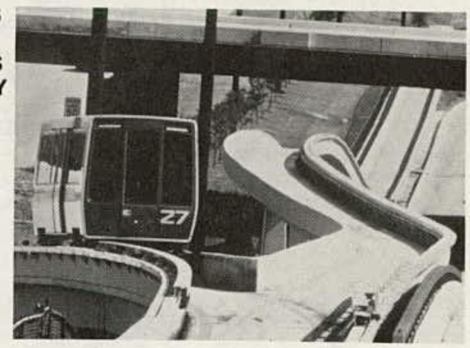


FIGURE 6
VIEW OF
AIRTRANS
GUIDEWAY

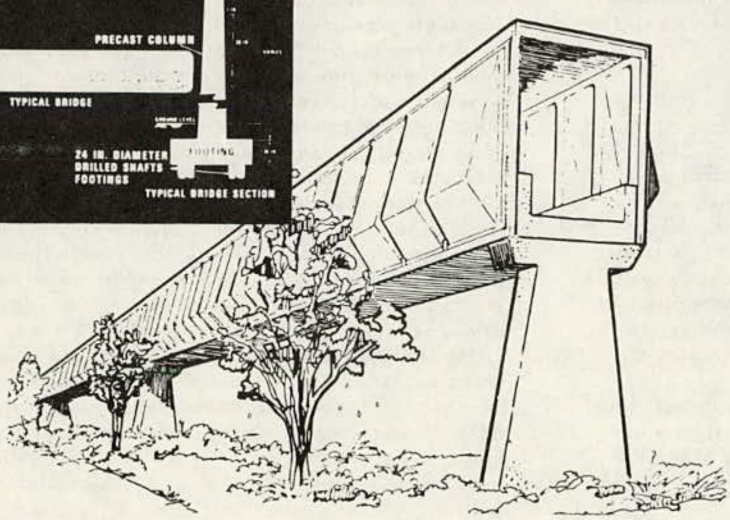


FIGURE 7
PLASTIC COVERED
GUIDEWAY CONCEPT

plastic interior panels are tastefully utilized within the vehicle.

The vehicles operate both as single and two-car consists. Each vehicle is 21 feet long, 10 feet high and 7 feet wide. The steel frame acrylic skinned fiberglass bodies are suspended on a chassis by air bag suspension units. Bi-parting doors are provided on one side and emergency egress doors are located at each end of the vehicle. Shock absorbing bumpers which can absorb 3 mph impacts are located at each end of the vehicle. Mechanical and electrical coupling is provided for multiple car operation.

Vehicle propulsion is provided by a 60 horsepower electric motor coupled through a differential and planetary gear reduction to the wheels. The motor is controlled by a controller which converts 480V, 3 phase, 60 hertz power into a variable voltage DC through SCR's (silicon controlled rectifiers). Drum brakes in the wheels are used for service and emergency braking. Service braking is pneumatic for application while emergency braking is spring applied with pneumatic hold off. Fail-safe operation is achieved since loss of pneumatic pressure causes application of the emergency brakes.

Steering of the vehicle is accomplished by polyurethane covered wheels in each corner of the vehicle which roll on the vertical walls of the guideway. These wheels are connected through a mechanical linkage to the Ackerman steering linkage mounted on both axles. Smaller wheels are provided in the same mechanism to engage entrapment rails in switch areas where the guideway walls spread apart. The entrapment rails and switch rails provide positive containment of the vehicle through diverge and merge switches. The 480V, AC power is brought onboard the vehicle by 3 collector brushes located at each corner of the vehicle (Figure 4). The brushes are a carbon/graphite material which slide on copper capped steel rails mounted on the guideway walls. The brushes are mounted on spring loaded arms made of injection molded FRP (fiberglass reinforced plastic). The geometry of the rails, particularly in switch areas, is arranged so that two brushes of each phase are always in contact with rails so that arcing never occurs.

In addition to carrying passengers, the AIRTRANS system is designed to carry cargo. Cargo vehicles which can carry 3 large containers operate in the same guideway, intermixed with the passenger vehicles. Special cargo stations which can automatically off-load and on-load any combination of the containers are provided throughout the system. The cargo vehicles are equipped with the same subsystems as the passenger vehicle except those functions particularly related to that vehicle's purpose.

AIRTRANS Guideway Configuration

A pre-stressed concrete box beam is combined with two parapets to form the channel-shaped structure (Figure 5) required to support the AIRTRANS vehicle system. The beam upper surface (or traction surface) is sloped toward the beam centerline to form a trough utilized to conduct water away from the vehicle wheels. The trough conducts the water to a low grade point where it is then introduced into a pipe submerged in the structure and then down a column into a storm sewer.

The parapet is utilized to position and support the wayside signal and power rails. Steering inputs are provided by the vehicle guidewheels acting along the parapets inner surfaces.

The parapet upper surface serves to support the switchblade and entrapment rails in the guideway merge areas. The switch actuating mechanism is housed in the box beam.

Most of the guideway features described thusfar are encompassed in Figure 6 which shows a segment of the AIRTRANS guideway. Note the channel shaped guideway, the power and signal rails and the entrapment rails.

The upper rail on the parapet inner wall is the signal rail, the next lower three are 480V power rails and the lowest is the ground rail. There are approximately 10 miles of at-grade guideway and 3 miles of elevated guideway.

Vought's Approach to Combatting AIRTRANS Ice and Snow Problems

The initial problems encountered by AIRTRANS in snow and ice conditions were: 1) loss of signal, power and ground continuity to wayside; 2) traction of the main support wheels. Comprehensive programs for both of these specific problems were established which involved laboratory and guideway testing.

Collector/Rail Interface. To adequately assess any potential solution to the collector/rail interface problem, a snow and ice test chamber with wind capability was required. Since comprehensive testing of the collector/rail interface dynamics had already been performed on a Vought-built 12 foot diameter test wheel, an environmental chamber was built around the wheel. Wind velocities of up to 40 mph were incorporated by using a blower and closed loop ducting arrangement. Test chamber cooling was accomplished through use of liquid CO_2 and ice was formed by cooling water to 33°F and then spraying it into the chamber. Initial operation of the chamber established that ice buildups of 1/8 to 1/4 inch could be easily and uniformly formed on the rails. At this point, development testing of the collector/rail interface problem was initiated.

Various brush configurations were evaluated to try to secure a scraping action removal of the ice. These included: cast iron, copper impregnated carbon, wood and other materials machined with grooves and flutes. All of these approaches were unsuccessful, and it was learned that a layer of ice (or frost) as thin as .01 inch was sufficient to cause loss of signal or power continuity. It had always been felt that the power rails would arc through the ice to the brush; however, this proved not to be true. The tests were performed by pulling the collector arms back from the rail while the ice was formed, and then dropping the arms to obtain contact. Although constant contact is not required for vehicle operation, the time of individual discontinuity permissible is quite short. As previously mentioned, the power collectors are arranged so that two brushes are always in contact with the rail. This also was incorporated in the cold chamber tests. Other approaches tried included a high contact pressure wheel to crush the ice and increasing the normal force on the scraping brush from 9 to a high of 40 pounds. Seventy-seven separate attempts were made to scrape or crush the ice from the rail before it was concluded that the ice bond was too strong to break mechanically. Several chemical treatments were tried unsuccessfully prior to experimenting with ethylene glycol. This solution successfully prevented the ice bond from forming and would not wash away immediately during rainfall. This material by itself, however, was not sufficient for satisfactory rail/collector continuity and it was determined through additional testing that:

1. The brush contact force would have to be increased by 50%.
2. A scraper (grooved) brush configuration of copper carbon material.
3. Heaters placed behind the brushes to keep ice from clogging the scraper grooves.

This configuration used in conjunction with the ethylene glycol on the rails produced repeatable satisfactory results and was considered acceptable for incorporation into the AIRTRANS system.

A spray rig to distribute the ethylene glycol was built onto an AIRTRANS utility vehicle and consists of an insulated, heated 200 gallon storage reservoir, a gasoline engine driven fluid pump, an insulated fluid distribution system, a front mounted manifold with attached shutoff valves and spray nozzles and an operator's cab containing the necessary controls. In operation, high pressure jet sprays are directed at operator selected portions of the channel-shaped guideway. Vehicle speed and fluid dispersal rates are matched to the conditions of the guideway. Pre-snow ice conditions or light snow conditions are conducted at normal vehicle speed (17 mph).

The spray rig has the additional capability of wiping the signal rail with the ethylene-glycol mixture when frost conditions are anticipated.

The sidewall mounted power, signal and ground rails and the wheel track running surfaces can be sprayed to provide an anti-adhesion coating prior to the formation of ice on the surfaces.

Preliminary studies of collector/rail heating were also conducted. These showed electric rail heating to have an initial cost of $768,000 plus an annual operating plus demand cost of $144,000 for eight days of operation. For the Dallas/Fort Worth area, this was not considered a cost effective solution.

Traction Surface. The traction problem on AIRTRANS appeared prior to the first ice and snow storm. This was caused by use of a "polishing" aggregate in the concrete, as specified by contract, and by grinding the concrete surface to assure the required vertical alignment. The grinding left a "terrazzo" like finish on approximately 25% of the guideway. To rectify the traction problem created by the "terrazzo" finish, longitudinal grooves were cut into the surface. While this helped the lateral traction of the tire, it reduced the longitudinal traction capability by some factor. The aggregate used in the concrete, crushed limestone, is the same as that used in Interstate Highway construction. Unfortunately, with repeated tracking of the vehicle over exactly the same surface area, even unground areas polished out at a rate of 4 to 6 times that encountered on Interstate Highways. The traction problems were observed initially on upgrades shortly after the start of a rain. In Texas, a layer of dust produces an excellent lubricant when moistened. A sustained rain will wash the surface with a resultant restoration of traction capability.

Based on the collector/rail tests, it was concluded that ethylene glycol would also prevent the bond from forming between the ice and concrete, and that the tire action would squeeze the resulting slush out of the tire track. While some lubricating effect of the glycol was expected, a reduction of traction capability of approximately 50% occurred, making upgrades and acceleration areas impassable.

Several approaches to the wet weather traction problem were considered. A temporary solution was implemented in critical guideway areas by bonding abrasive (course sandpaper) to the guideway track. This immediately corrected the wet traction problem and lasted longer than anticipated (over 9 months).

Considering the snow and ice traction problem along with the wet traction problem and the need for a long term solution, several other approaches were evaluated. These approaches included:

1. Mechanically attaching an expanded metal grid (1 3/4 x 3 1/2 inch diamond shaped) to the guideway surface. While this proved effective in icing conditions, chunks of rubber were shed from the tire in high torque conditions. Normal operation did not damage the grid or tires.
2. Sand spread on the traction surface was found to be a clean-up problem, would accelerate brush wear and contaminate the traction motors and other mechanical equipment.
3. Urea, a nitrogenous compound ($CO(NH_2)_2$) used on airport runways as a deicer was tried and found to be corrosive to copper (used on the collector/rail faces) and potentially the reinforcing steel in the concrete.
4. Explosive driven nails and nails in pre-drilled holes with anchors in the traction surface were evaluated. The explosive nails were driven with a 22 caliber charge and protruded 1/4 inch above the surface. Since the concrete was completely hard (two years old), cratering of the concrete occurred as much as 1.5 inches in diameter by 3/8 inch deep. Pre-drilling the holes and using anchors was considered excessively expensive. Spacing was such that only 2 nails were engaging the footprint at a time and rubber chunking was feared in a high torque condition along with minimum traction improvement.
5. Studded tires were evaluated on one vehicle operating on a particular route. Within two weeks, longitudinal grooves were detectable in the guideway in select areas of that route. Studded tire tests were stopped prior to encountering an icing condition in the guideway. Extensive guideway damage seemed apparent had the entire 68 vehicles been converted to studded tires. Estimates from highway data indicated with all cars equipped with studs we could expect 0.15 inch concrete wear per month.
6. Walnut hull impregnated tire retreads were evaluated to improve traction. While this seemed to be an improvement over the standard tires for wet traction, the magnitude was insufficient to be worthwhile for ice conditions.
7. Cross grooving of the traction area was evaluated in a 25 foot section of guideway. No spalling was observed during cutting; however, after only 50 vehicle passes, sufficient spalling had occurred to make this approach unacceptable. This may have been caused in part by the longitudinal grooving mentioned before which resulted in a waffle pattern on the surface.
8. A change to the control system to reduce to jerk rate (rate of change of acceleration) and the acceleration rate were considered since it had been observed that a vehicle under manual control could accelerate up a grade that a vehicle under automatic control could not. Development in the control system was initiated and is still being pursued.
9. A limited slip differential was installed in one vehicle for evaluation. While it operated satisfactorily as a differential, the increase in traction before breakout occurred did not warrant modification.

A slight clicking noise occurred in turns (80% of the D/FW AIRTRANS guideway is in turns). The clicking was a negative factor to consider.

10. A hot air blower unit was mounted on the front of a vehicle to evaluate melting the ice particularly from the rails. Although this was not evaluated on the traction surface, for the rails it proved unsatisfactory because the quantity of heat required was enormous when the vehicle was moving at any speed at all, and the water refroze as soon as the vehicle passed by, resulting in a condition potentially worse than what it had been before the vehicle went by.

11. Prior to turnover of the system to D/FW Airport, Vought concluded that a traction course of epoxy mixed with a fracturing (as opposed to polishing) aggregate such as calcined bauxite, aluminum oxide, carborundum or sandblasting sand (slag) should be spread over all areas of the guideway that exceeded 3% grade, and normal acceleration areas that are subject to rain (approximately 4 miles). After D/FW Airport took over operation, they applied an epoxy aggregate course in known traction problem areas.

Coincident with the collector/rail and traction surface programs, a chemical evaluation of the possible detrimental effects of various deicing and cleaning compounds on the guideway and rails was performed. Included in the study was urea, sand, "DuBois DeIce", commercial antifreezes (ethylene glycol, propylene glycol, Quaker Maid, Preston, Zerex and Rain-Bo) and commercial detergents (Vel, Triston X-100, Turco). All of the materials tested on copper-iron rails and reinforcing bars show corrosion, the commercial antifreeze mixture showed the smallest attack. Urea and urea combined with all the above materials show increased corrosion of iron. The "DeBois DeIce" compound severely attacks copper, but does not significantly affect iron. The Vel or Triston X-100 are good cleaning agents for the rails. The Turco detergent both corrode the copper rail. Sand will not interact with any of the materials tested to aggravate corrosion.

D/FW Procedures for Operation of AIRTRANS in Severe Weather

Severe weather conditions are anticipated through the monitoring of all available weather information by the D/FW Airport Operations Department. The sources of information include the U.S. Weather Bureau and airline reports. When indications dictate, one of the following conditions is declared by the Operations Department:

1. Weather Alert. When all available information indicates that a potentially hazardous weather condition will be in the area of the airport within 24 hours.
2. Weather Emergency. When all available information indicates that a potentially hazardous weather condition will be in the area of the airport within the next 6 hours.

When a Weather Alert is declared, preparations are made to respond to a Weather Emergency. These include notification of personnel and standby equipment and readying the AIRTRANS spray rig. The spray vehicle is parked in the Trash, Dump and Wash siding. The reservoir is filled with a mixture of ethylene glycol and water. The reservoir thermo-controller is set at 180°F. Six 55-gallon drums of the mixture are placed in a supply container onboard the vehicle and drum heaters attached. The drum heaters are also set at 180°F.

Two hours prior to forecast of severe weather onset spraying of the guideway and rails is initiated. The areas to be sprayed depends on the type of weather anticipated. Removal of the AIRTRANS system from revenue service is a judgment by the Central Control Supervisor based on the forecast. When removal from revenue service is initiated, the passengers are off-loaded at stations and the vehicles stored in the terminal building. A backup bus system is then activated which transports the passengers over the motor vehicle roadway.

The spray rig continues to operate until the entire guideway system is coated with glycol or until weather conditions deteriorate so that operation must be halted.

For snow or ice accumulations which exceed the capability of the spray rig, manual removal techniques are used after the accumulation ceases. These methods include the use of self-propelled portable snow blowers and shovels. Experience has shown that the application of ethylene glycol prior to ice/snow accumulations greatly eases the subsequent removal operations.

These techniques have enabled the AIRTRANS system to maintain normal operations during frost conditions and have permitted rapid return to service following snow or ice accumulations which required cessation of operation. Actual levels of service achieved during the past 2 years are compared below. It should be noted that the service availability values are based on a system operational time of 24 hours a day, 365 days a year.

Table 1. Levels of service achieved during past 2 years.

Calendar Year	Service Avail. Total	Service Avail. Exclusive of Ice/Snow	Total Hours Lost Due to Ice/Snow
1978 (thru 3/4/78)	76.0%	98.7%	344
1977	95.1%	97.4%	214
1976	97.5%	98.0%	33

Alternate Approaches to Ice and Snow Control on AGT Guideways

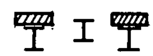
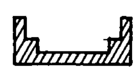
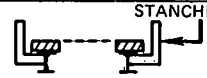
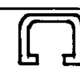
The foregoing discussions dealt with the ice and snow measures that were developed specifically for AIRTRANS: an existing system at a particular airport in a moderate climate. If the candidate solutions for that situation seem numerous, then, the list of alternatives is, indeed, even greater when one is free to consider a wide choice of feasible approaches. Such latitude might be the case during conceptual design or when considering a new installation. The diversity of ice and snow measures for AGT systems is illustrated by the tabulations on Table II. This table attempts to name the different approaches that are feasible or that are backed up by some precedent. From this wide choice of alternatives, the correct solutions for a given AGT installation are dictated by many factors, most of which are constraints resulting from considerations of:

TABLE II SNOW AND ICE CONTROL METHODS

I. GUIDEWAY MEASURES
- A. Traction and Snow Handling
  1. Covered Guideway
  2. Subway
  3. Wind Swept Guideway
  4. Tractive Surface Treatments
  5. Elevated Guideway
  6. Snow Plows
  7. Snow Blowers
  8. Sanding
  9. Salting and Other Solid Chemicals
  10. Spraying Glycol Solution
  11. Spraying Methanol
  12. Heating with Pipes and Pumped Fluids
  13. Heating with Buried Electrical Wires
  14. Heating with Low Voltage on Buried Mesh
  15. Heating with Conductive Asphalt
  16. Heating with Earth Heat and Heat Pipes
  17. Heating with Flowing Ground Water
  18. Heating with Radiation
  19. Continuous Blowing with High Velocity Air
  20. Coating with Hydrophobic Films
  21. Elevated Gratings for Running Surface
  22. Steel Rails (With Steel Wheels)
  23. Linear Induction Motor
  24. Aerial Tramway
- B. Collector and Control
  1. Rail Heating
  2. Covered or Enclosed Rails
  3. Inverted Rails with Side Covers
  4. Glycol Spray
  5. Rugged Steel Rail (With Aggressive Scraping)
  6. Flexible Catenary Overhead (With Scraper)
  7. Inductive Control (Contactless)

II. VEHICLE MEASURES
- A. Traction
  1. Tire Chains
  2. Steel Wheel (On Steel Rail)
  3. Studded Tires
  4. Snow Tires
  5. Positive Cog Drive
  6. Linear Induction Motor
  7. Slip/Slide Systems
  8. Reduced Speed
  9. All Wheel Drive
- B. Collectors
  1. Brush Heating
  2. Scraper Brushes
  3. High Contact Pressure
  4. Servo-Aimed Laser to Loosen Ice From Rails
- C. Systems and Components
  1. Heating
  2. Shielding
  3. Periodic Cleaning with Hot Water Spray
  4. Vortex Separators on Air Intakes
  5. Hydrophobic Paints
  6. Ice Scrapers on Piston Rods
  7. Air Inflated Boots
  8. Ice Excluding Designs
  9. Ice Tolerant Designs

TABLE III
PRINCIPAL FEATURES OF PROMINENT AGT SYSTEMS

SYSTEM	SUSPENSION			PROPULSION			GUIDEWAY TYPE
	RUBBER TIRE	AIR CUSHION	STEEL WHEEL	COLLECTOR RAILS	CONVENTIONAL ELECT. MOTOR	LINEAR MOTOR	
Westinghouse	X			X	X		
Unimobil	X			X	X		 STEEL BOX GIRDER
Rohr "P"	X			X	X		
Ford ACT	X			X	X		
AIRTRANS	X			X	X		
Morgantown	X			X	X		STANCHION 
Wedway			X			X	
Cabinenlift	X			X		X	
Otis		X		X		X	

- economics or cost
- implementation
- function or effectiveness
- aesthetics.

Of the alternatives shown on Table II, some might provide a complete solution and others are best utilized in combination.

A survey of the candidate DPM* automated guideway systems quickly reveals the majority are rather conventional, electrically powered vehicles running on a dedicated guideway or surface. Table III attempts to identify the principal features of these systems. The features they have most in common are open guideways, rubber tires and rail/collector systems. Some of these systems display a degree of natural tolerance to ice and snow. However, it is toward those conventional vehicle systems that the bulk of ice and snow operational developments is directed.

Clearly, the most effective means for all-weather operation is provided by "protected" guideway systems which includes subway, covered guideways (Figure 7) and those monorails wherein the tractive components run inside the suspension beam. These are completely effective because they do not expose any of the functional aspects of the system to weather. Each of these approaches, however, are characterized by some undesirable constraint: subways are prohibitively costly for most installations; covering the entire above-ground guideway may meet with objections for their cost and aesthetic intrusions (especially in downtown scenarios). Overhead monorails enjoy wide use but in some instances impose certain requirements on vehicle characteristics and pose aesthetic concerns for certain applications. These objections are probably more intense in the DPM application because of the fact that the systems will be installed into available space of an already developed business district. The environmental and safety concerns weigh heavily.

Next in terms of inherent all-weather effectiveness are steel wheel/steel rail concepts. There is vast experience with steel wheel/steel rail in heavier equipment and they are inherently ice and snow tolerant where traction is concerned because of the ability of the small area, high stress situation to break down and melt the ice. Rail systems, however, have experienced only limited consideration for AGT vehicles because conventional rail usage concepts bring on aesthetic and operational objections when they are applied to AGT type scenarios.

The conventional vehicles that comprise the majority of automated vehicle systems rely primarily on rubber tires and more or less conventional suspensions. Seven of the nine DPM-approved systems fit this category. If the guideways of such vehicles are chosen not to be covered, then the vehicles and guideways will be subject to weather and their ice and snow operational problems can be categorized:

- traction
- accumulation removal
- power and signal rails functioning
- on-board systems functioning.

The problems are not unlike those we have all experienced with automobiles in severe winter weather, except that power rail icing presents some new and unique problems. Indeed, we go to highway departments for some of our most feasible solutions to ice and snow operation.

*Downtown People Mover (DOT Demonstration Program)

Guideways Deicing - Snow Removal

Removal of snow accumulations from guideways is achieved by either mechanical removal (plowing or snowblowing) or, in the case of heated guideways, by simply providing drainage for the melted snow. The unique problems associated with plowing or blowing have to do with adaptation of equipment to peculiar guideway shapes and disposal of the snow that has been removed. Disposal is often a problem because AGT guideways are frequently routed above streets, parking lots, etc., so that it is not permissible to merely "dump it over the side". Hence, the requirement to collect and dispose of it. A snow-melting transport vehicle concept similar to that in use at JFK Airport is attractive because of its ability to transport large quantities in the melted form; e. g., fewer service disruptions by snow removal vehicles.

Once the running surface is snow plowed, the remaining ice layer or compacted snow layer still requires removal to provide traction. Salts and other chemicals are known to be a cost effective means of clearing these thin surface layers on highways. However, due to recently well-publicized latent problems associated with chemical use, plus the labor intensive nature of their application, chemicals, in general, find disfavor in automated guideway systems. Chemicals create additional problems in the vast electrical and signaling systems associated with automated guideway transit.

Traction improving devices have been used extensively in other modes of transportation. These include chains, stud tires, sand, etc. These are even less attractive for automated vehicles because of their cost of implementation, damage to the guideway and, in the case of sand, requirement for subsequent removal. All these approaches impose a heavy burden on maintenance manpower.

One category of special running surfaces includes those approaches that "shed" ice and snow or make it possible to be easily scraped away (see Table II). Experience with bridges and elevated approaches using open metal mesh or grate type running surfaces indicate a degree of effectiveness of these surfaces in permitting ice and snow to fall or be passed through these meshes and leaving the surfaces in reasonably good condition. Decreased normal traction, greater tire wear, noise and less than complete effectiveness are the undesirable characteristics of such surfaces.

A new surface treatment development that shows promise is a hydrophobic coating. Such a coating, which might be a silicone or other durable release agent, is applied to the running surface prior to precipitation and acts to prevent bonding of ice to the running surface. Traffic or scraping can then keep it broken up. The EPA has sponsored attempts to develop a practical coating. A somewhat similar approach or action might be afforded by a flexible running surface that flexes sufficiently to break up the ice. This approach will be evaluated under a future AIRTRANS program.

Clearance of ice and snow by heating of the running surfaces is an alternative that continues to gain increased use on highways, sidewalks and on automated guideways. Heat is usually supplied to the running surfaces by embedding heated fluid tubes or electrical resistance elements under the running surfaces. The energy might be supplied from a number of different sources (see Table II). Thermal anti/deicing is attractive for automated guideways because:

- it is effective
- heating systems are easily automated and do not impact the labor force requirements
- since AGT vehicles are guided, they track and therefore, only a narrow strip of pavement requires heating instead of the full width; this reduces energy use per lane
- a variety of energy sources can be used, including low temperature natural sources
- melting also alleviates the need for removal of bulk accumulations.

Guideway heating, however, is expensive, both in capital costs and operating costs. Electrically heated systems are less expensive to install than fluid systems, but are more expensive to operate, since, depending upon local conditions, electrical heat costs two to three times more than fossil fuel heat. The selection of electrical versus fossil fuel energy then is a tradeoff subject that depends upon annual energy usage and projected future cost escalations of energy.

The use of earth thermal storage and geological heat for roadway heating have both been demonstrated in highway applications and have been proven to be feasible. Using the thermal storage of earth (depths to 50-75 feet) is costly in that a large amount of heat transfer surface (pipes) must be put into the ground. Both heat pipes and active fluid loops have been proven practical for transporting the heat up to the surface. The essentially zero operating cost of such an installation can, over a period of years, offset its higher capital costs.

Geological sources (natural warm or hot water) are utilized by pumping the warm water through a heat exchanger to the circulating fluid. The operating costs are only the pumping power and maintenance. An installation of this type operates successfully in Oregon.

Solar energy for heating is very expensive and, based on at least one study, could not compete with earth or geological heat because of the heat storage requirement. Perhaps solar energy in combination with earth storage would prove a practical combination for certain sites.

Hydrokinetic removal of snow and ice (Table II) is the use of large quantities of low temperature water, at sites where it might be available, to melt ice and snow by simply flowing the water over the guideway surface. The water is drained off at certain intervals and more applied. Hydrokinetics has been used on highways in Greenland, the Scandinavian countries, and in Japan.

One demonstrated method of reduction of guideway heating costs is to restrict heating to only critical guideway sections: steep grades, station approaches, switches and merges. This is possible because it has been shown that vehicles can be operated on level non-critical sections of guideway under reduced traction conditions by employing a combination of:

- removal of appreciable snow accumulations
- 4-wheel drive
- anti-slip/slide controls
- degraded cruise speed.

This approach emphasizes that combinations of actions are likely to be the optimum approach to operation of rubber tired vehicles in exposed guideways.

Power and Signal Rail Anti-Icing

Keeping the collector system free of ice is a must. The application of electrical heat to the rail is practical for short spans, but there is little experience with long spans. The first AGT system to employ long spans of heated rails will be the Morgantown Phase II system. Hard steel rails with cast iron scrapers can be made to work with adequate pressure applied to the scrapers. Rail covers can be used; however, they interfer with switching and rail maintenance.

Application of chemicals such as glycol is effective for a short time but should not be considered a complete solution. By-products of these chemical agents are current leakage, and guideway cleaning tasks.

Recommendations

The winters of 1977 and 1978 will probably go down in history as the most severe weather periods on record. Not only does this apply to the classical winter areas but to the so-called sunshine belt of Florida through Texas to California. Cities in all regions of the country planning conventional or AGT systems must utilize a Systems Engineering approach to determine hardware requirements for their site-specific application to address their severe weather operational requirements. This scheme will match system performance requirements with the most cost effective methods available at the time.

Conclusions

Nature has demonstrated a disdain for all our systems the past two years and will continue to challenge our best efforts in this area. Although there is a long shopping list of options available for combatting ice and snow, better means are needed. Also, most of the options discussed in this paper have been investigated to a very shallow depth and in most cases their potential benefits to AGT applications have been extrapolated from data related to airports, highways, automobiles, railroads, aircraft and the construction industry.

The investments required to research these potential methods are substantial and should be funded by the Federal Government. A program planned and executed on a timely basis which includes basic engineering analytical techniques, laboratory experiments, followed by full scale hardware testing in the weather regions which produce the baseline weather, will insure that the American people have dependable mass transportation when all other forms of people movers are stuck in the snow.

Bibliography

1. Proceedings of an International Symposium held April 8-10, 1970, "Snow Removal and Ice Control Research", Special Report 115, Highway Research Board, Division of Engineering. National Research Council . National Academy of Sciences . National Academy of Engineering, Washington, D.C.
2. W. B. Bienert, Dynatherm Corporation, "Snow and Ice Removal from Pavements Using Stored Earth Energy", Federal Highway Administration, NTIS PB 240 623.
3. Bernard K. Barrocliff, Ford Motor Company, "Operating the Ford AGT System in a Snow and Ice Environment", 1975 International Conference on Personal Rapid Transit, Volume II.
4. MPC Corporation, Pittsburgh Pennsylvania, "Transit Expressway Report", and "Transit Expressway Report Phase II", (Southpark Demonstration Project).
5. Lea Transit Compendium.
6. Donald M. Murray and Ulrich Ernst, ABT Associates, Inc., "An Economic Analysis of the Environmental Impact of Highway Deicing", U.S. Environmental Protection Agency EPA-600/2 - 76 - 105, May 1976.
7. G. H. Ahlborn, H. C. Poehlmann, Jr., Ball Brothers Research Corporation, "Development of a Hydrophobic Substance to Mitigate Pavement Ice Adhesion", EPA-600/2-76-242, December 1976, Environmental Protection Agency.
8. M. F. Pravda, et. al., Dynatherm Corporation, "Heating Systems for Airport Pavement Snow, Slush and Ice Control", U.S. Department of Commerce, NTIS AD-A020-757.
9. Highway Research Record Number 477, "Winter Driving Traction Aids", 1973.
10. American Public Works Association, Special Report No. 42, "Managing Snow Removal and Ice Control Programs", 1974.
11. T. E. Lucier - Airport Snow Control - Airport World November 1970 (Snow Melters).