# EVALUATION OF A FIXED ANTI-ICING SPRAY TECHNOLOGY (FAST) SYSTEM

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## Abstract

This paper describes the in-house development (Phase I) of the Fixed Anti-Icing Spray Technology (FAST) systems to apply less corrosive liquid chemical freezing - point depressants on portions of the south-roadway (Manhattan-side span) of the Brooklyn Bridge. During the first phase of the project, several operational parameters were investigated, including spray pattern, spray angle and spray pressure. Two homegrown FAST systems were installed. The first system consisted of the installation of pipes on both sides of the roadway, with spraying activated simultaneously through nozzles spaced 20 feet apart and 6-8 inches above the roadway surface. The second system – which was installed on only one side of the roadway – was intended to achieve sequential spraying. During this phase, the FAST systems were manually activated. Phase II of this project describes the proposed extension of the FAST system and integration of a road weather information system (RWIS).

## I. Introduction

The Brooklyn Bridge is the oldest of the East River bridges and connects the Boroughs of Brooklyn and Manhattan in New York City. It was opened to traffic in May 1883 and designated a Historic Landmark in 1967. It is a combination suspension/cable-stayed bridge with a main span of 1595.5 feet and two equal side spans 933.2 feet. At the time of construction, it was the longest suspension span in the world. The bride has four main cables (A, B, C, D north to south), each 15.75 inches in diameter. Granite masonry towers and anchorages support the cables. As the transportation mode changed over time, the bridge was reconfigured to accommodate the increasing transportation demand. In the late 1940's, the roadway was replaced with a concrete filled steel grid deck supported by steel I-beam stringers placed over the original truss floorbeams. Thus, the bridge, in its current configuration, has three vehicular lanes each way with an AADT of 140,000 (passengers car only).

In 1995 and 1996, the FHWA conducted a maintenance review of the Division's preventive maintenance program on the East River Bridges (ERB). The reports recommended that the Division develop and initiate aggressive short-term and long-term preventive maintenance strategies that would serve to extend and preserve the useful life of its bridges, and protect the highway community's investments. Years of heavy sodium chloride (salt) use on the ERB have resulted in extensive corrosion of the bridges' roadways and structures. This roadway de-icing method has resulted in costly and often premature roadway and structural repair. During the summer of 1998, when the overlay was being replaced, it was discovered that the concrete fill in the 50-year old deck was failing due to excessive salt in it, allowing the corrosion of steel grid members. Thus, the entire suspended span decks were replaced at the lowest bid price totaling $33,357,000.00 dollars.

## The Objective

The objective of this paper is to provided an evaluation of the FAST system's (System 1) performance during the '98-'99 winter season and subsequent winter seasons. Also embedded within this objective is the evaluation of the following performance goals and criteria for the FAST system:

- Improve service delivery to the motoring public with the safe, timely and rapid application of chemical to the bridge's roadway.
- Monitor vehicles tire tracking and carry-over distance.
- Evaluate and monitor drivers' reaction to spraying via an automatic system.
- Evaluate the system's in-use reliability.
- Evaluate and compare conventional over-the-road method utilizing trucks
- Establish wide-scale implementation parameters and feasibility (cost and cost effectiveness) goals

## Scope of Evaluation

This evaluation will investigate the operation and performance of the FAST system (system I) during the 1998-1999 winter season and subsequent winter seasons. Of primary technical concern in this investigation were the capabilities and reliability of the system's components: spray nozzles, PVC piping on the south roadway barrier and the check valves. A cost-comparison between the conventional over-the-road method utilizing spray trucks and the FAST system will be investigated.

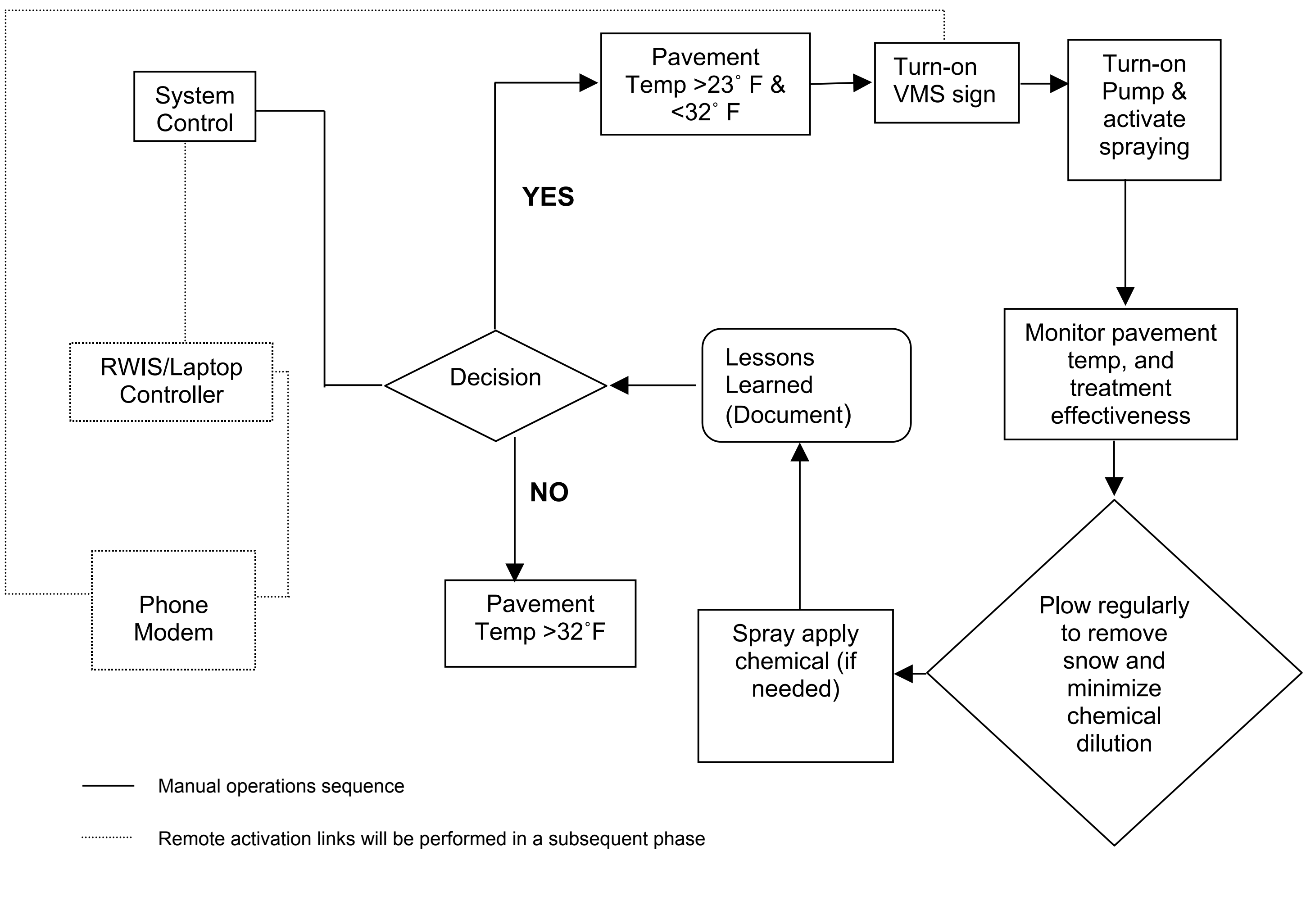
## Methodology of Evaluation

The weather forecasting methods used were not site specific to the bridges' roadways. A Road Weather Information System (RWIS) was not integral into the decision making process during the season (the integration of a RWIS is discussed under *Phase II* of this project). As a result, weather forecasts and the decision to initiate anti-icing procedures were primarily based upon broadcast radio and television weather forecast reports. **Chart A** outlines the operational procedures adopted and followed during each weather event the FAST system was utilized. A designee from the Division's Maintenance Unit was assigned to coordinate operations with the Department of Sanitation (DOS). This person was further responsible for initiating call-out procedures for the Division's winter operation crews. Call-out procedures were initiated based on a forecast threshold of a >60% chance of precipitation occurring. The process consisted of the designee contacting (via telephone) and informing each respective operation managers/supervisors (FAST and Truck crew) of the decision to mobilize crews.

However, once the crews were mobilized, the on-site decision to initiate anti-icing techniques was determined by the respective operations' supervisor. This decision was generally based on the pavement temperature estimated to be 5˚F-10˚F lower than the ambient air temperature. The treatment recommendations outlined in the *Federal Highway Administration's Manual of Effective Anti-icing Practices* [1] were followed for the corresponding event type.
A Variable Message Sign (VMS) was utilized to provide advance warning and information to the motoring public with regarding the spraying. Also a CCTV system was utilized to monitor the site.

Supervisors followed and recorded field data based on the procedures outlined on the TAPER[1] logs. This information was later summarized and evaluated.

**CHART 1: FAST OPERATIONAL PROCESS SEQUENCE**




[1] TAPER is the acronym for: Ta=Time of Application; T=Low temperature since last application; A=Application rate (gallons/lane-mile); P=Product used; E=Event; R=Results

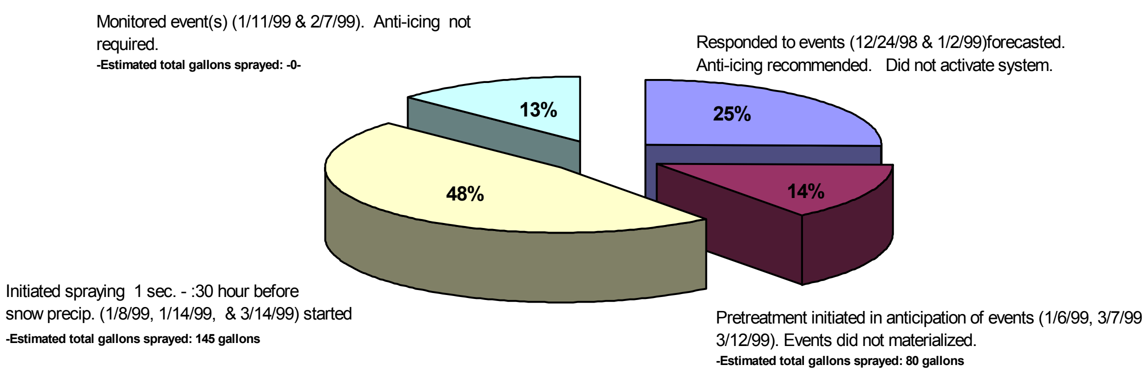
## II. EVALUATION OF FAST SYSTEM'S PERFORMANCE GOALS AND INDICATORS

During the 1998-1999 winter an evaluation procedure was implemented in an effort to determine the effectiveness of the FAST system. The evaluation plan for this project *(submitted as part of the initial Project Proposal)* outlined and targeted the following performance goals and indicators for this phase (phase I) of the project:

- Mechanical Performance
- Chemical Performance
- Cost Analysis

An operation team consisting of two workers responded to ten separate weather events during the '98/'99 season. These events were categorized (see Chart 2) as follows:

**Chart 2: 1998/99 Event-Response Categories**




Note: Percentages are based on operation cost .

A site-specific weather forecast information system was not utilized in determining whether to initiate a treatment, and when to start. Overall, a total of seven events (52%) were classified as follows: delayed responses; events that did not materialized, and events not requiring anti-icing. This inability to accurately predict storm and pavement temperature and to communicate rapidly changing conditions before treatments were initiated resulted in unnecessary expenditures. The decision to pretreatment the roadway and average of thirty-two (32) hours before an event materialized occurred on three (14%) occasions during the season. However, these actions aided the evaluation by providing some critical information pertaining to the residual effects of a treatment on the roadway. As anticipated, the chemical (potassium acetate) was not as effective after this lapse of time before the event started. Based solely on observation, traffic volume was considered to be a major factor in "removing" the chemical from the roadway. In fact, treatment made >1hour before an event invariably required retreating. The converse to pre-treatment was the decision to delay treatments in an effort to ascertain if a storm is of sufficient magnitude before initiating spray treatment. This situation occurred during of the first two events (12/24/98 and 1/2/99) of the season. While the conditions warranted anti-icing treatments, treatments were made utilizing truck mounted spray units. Similar decision-making was followed for the events anticipated on 1/11/99 and 2/7/99. Fortunately, these events (13%) did not meet the threshold temperature required to initiate anti-icing techniques. As a result, no action was taken to spray the roadway. The total reliance on broadcast media or the operation managers' judgment was not adequate and specific enough for effective decision-making.

The forecast certainty (> 90% chance of precipitation) of the 1/8/99, 1/14/99 and 3/14/99 events resulted in spraying being initiated literally seconds before the events started. An analysis of these events and the treatments initiated indicate that the roadway section treated via the AISDS provided a higher level-of-service in comparison to the adjacent roadway sections treated with an over-the-road method utilizing truck mounted spray units. Photo exhibits A-G below illustrate the various pavement conditions observed during the events.

Photo Exhibit A: Pavement condition of roadway section sprayed with FAST system (3/14/99)

Note: Photos are for illustrative purposes.
Brooklyn Bridge south roadway

Photo Exhibit B: Location sprayed with Truck mounted spray unit (3/14/99)

Initially, the decision to initiate anti-icing during the March 14, 1999 event was marginal. This was partly due to the weather forecast prediction that temperature would be steadily increasing during the course of the event. Under these conditions, icing of the roadway was unlikely. However, snow precipitation was predicted to be moderate to heavy, with accumulations totaling 4.5 inches. In addition, the snow was of a wet[2] consistency. Nevertheless, a treatment was initiated second after the event started. Photo Exhibit A and B illustrates the pavement condition between the hours of 8am-10am. It is critical to note, that plowing is recommended for this type of event and accumulation total. However, none was observed during this period. A key consideration in the decision to spray the roadway under these conditions was an attempt to discourage the DOS's crews from salting the roadway by default. However, despite bare "black" pavement conditions, a DOS truck was observed salting the roadway (see photo exhibit C) despite the pavement condition.

The photo exhibit below depicts an event on March 7, 1999 where a DOS salt truck was observed salting the pavement (black pavement conditions). This event did not materialized.

[2] Wet snow is a 10:1 snow to liquid ratio; Dry snow is a 20:1 snow to liquid ratio

Photo Exhibit C: NYCDOS salt truck salting the Brooklyn bridge south roadway (3/7/99)

While the rationale for the treatments is unexplained for the conditions reported, a similar action was also observed during the January 14, 1999 event. Based upon the evaluation of the event, maintaining a bare "black" pavement condition required minimal snow removal. The information recorded indicated that the pavement temperature was estimated to be ~23˚F; the ambient temperature was 27˚F and snow precipitation was dry with accumulations totaling >2 inches. The pavement section treated with the FAST system achieved the best pavement conditions ("black conditions") compared to the other section treated by the spray truck (see Photo Exhibits D and E). As photo exhibit D illustrates, a dry slush-like residue (<<1 inch) remained on the roadway in comparison to the section treated with the spray truck (see Photo Exhibit E). A subsequent treatment was initiated during the event in an attempt to achieve black pavement conditions. However, the slush-like residue remained on the pavement as illustrated. DOS salt trucks were witnessed salting the roadway later into the event-day. Photo Exhibit G illustrates the pavement after the salting occurred.

Photo Exhibit D: Pavement condition before re-treating (1/14/99)

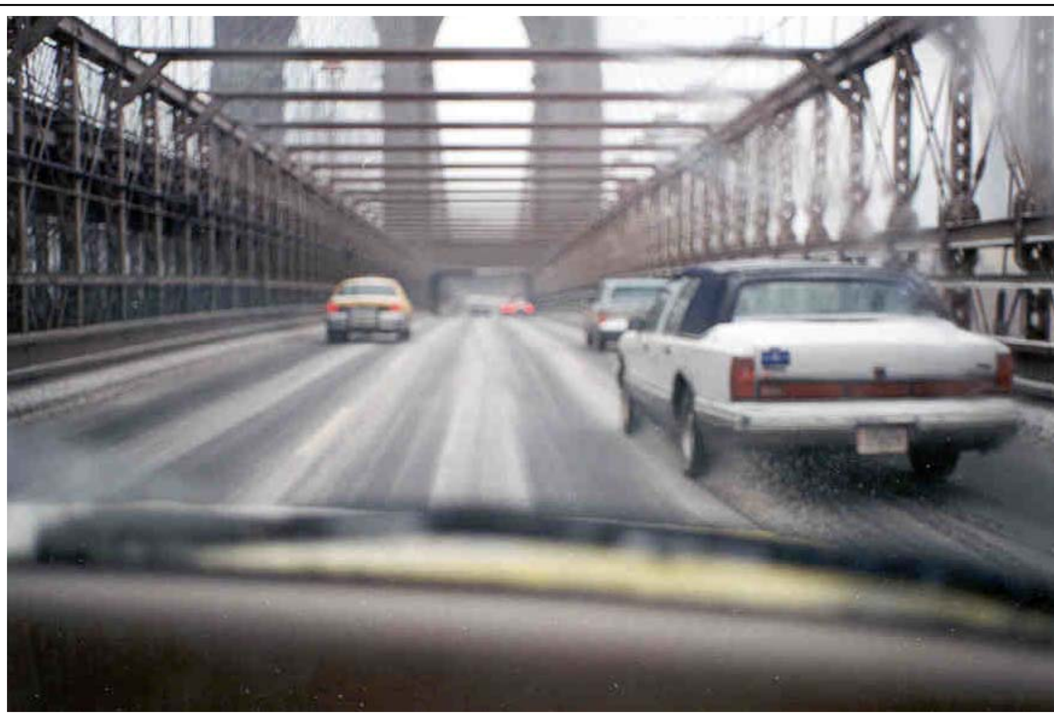


Photo Exhibit E: Road section treated by spray truck (1/14/99)

Photo Exhibit F: North roadway pavement after >4 passes of DOS salt trucks (1/14/99)

Photo Exhibit G: Pavement condition after DOS applied salt. (Note: Photo D illustrates the pavement condition before salting occurred (1/14/99).

Preliminary results indicate the effectiveness of timely and rapid spray applications utilizing the FAST system on the Brooklyn Bridge with a reported average daily traffic (ADT) volume of 147,898 to be safe and effective. Also, the integration of a RWIS and plowing equipment are necessary tools for an effective anti-icing program.

## MECHANICAL PERFORMANCE

Evaluation of the AISDS mechanical performance has been broken-down into the following categories:

➢➢ FLUID DELIVERY: In order to spray the recommended quantity (0.5 gallons per 1000 sq. ft.), of potassium acetate (CF7) required for the initial application, a spraying time of 2-3 seconds was required. The spray time duration is based on the capacity of each nozzle (3-GPM) and the total number (50) of nozzles utilized. Photo Exhibit H provides an illustration of the FAST system spraying in progress.

Photo Exhibit H: FAST system spraying (1/14/99)

➢➢ **EFFICIENCY**: The efficiency of the FAST system was measured by the following:

► Spray area coverage

► Reliability of the system's components such as:

- Spray nozzles
- Check valves
- PVC piping on the south barrier

Spray area coverage

The initial goal established was to achieve a spray coverage distance of three wheel paths from the curb barrier. This goal was achieved as a result of the nozzle angle and spray pressure (70psi) established.

Reliability of the System's components

While each component is critical to the overall operation and performance of the FAST system, special focus was directed to the following components:

- Spray Nozzles: The nozzles' capacities are 3 gallons per minute (gpm) each, with a 15° degree spray angles. The nozzles were self-cleaning and generated negligible misting that would not impair drivers' visibility.

- Check Valves: The absence of an in-line filtration system had initially resulted in residual debris in the pipe being deposited in the valves spring mechanisms. This condition was initially observed and addressed during the early testing phases of the system. However, this occurrence was infrequent during the season.

- PVC Piping: Schedule 80 PVC pipe was installed on the south roadway barrier. A major concern has been the durability of this pipe exposed to the elements. The concern was would it become brittle and break as a result of extreme ambient weather conditions, and when: year-one, year-two or year five. This did not occur during the '98/'99 winter season- the second year of the system's installation- but it was observed that some of the joints were discolored and moist. The discoloration can be attributed to airborne dust and debris. The moisture at some of the joints was as a result of the glue's failure. Commercial PVC pipe glue was used. During subsequent winter seasons –'99/'00 and '00/'01- failure of the PVC pipe joints occurred.

Photo Exhibit I: Typical joint failure

➢➢ **DRIVER REACTION:** There were no adverse reactions observed to the sprays.

➢➢ **MAINTAINABILITY OF SYSTEM:** Maintenance consisted primarily of scheduled and periodic cleaning of check valves. Repair of broken and leaky joints is accomplished by a worker easily saw cutting PVC pipe and using couplings, reconnect the jount.

Photo Exhibit J: Typical joint repair

➢➢ **LEVEL OF SERVICE**

It is important to note that a qualitative comparison of pavement conditions indicate that the level of service of the roadway treated with the FAST system had significantly less accumulated snow that the section tread via conventional methods utilizing a spray truck (see photo 1 and 2 for illustration).

Photo 1: Road section sprayed by the FAST system

Photo 2: Road section sprayed with truck mounted spray unit

## CHEMICAL PERFORMANCE

Potassium Acetate (CF7) (Chart 3: Phase diagram [1]) was utilized during the events the FAST system was utilized during the '98/'99 season. This chemical was effective as an anti-icer. Information pertaining to the residual concentration of the chemical on the roadway was not "scientifically" monitored and obtained. This information is generally obtained from solution detection sensors installed on the roadway as part of a RWIS. The installation of an RWIS is proposed as part of the Phase II of this project. In fact, the presence of these sensors will enhance the abilities of the decision-makers as to how far (time) in advance a treatments should be made considering deck and pavement types and the average daily traffic (ADT) volume on the bridge.

It should also be pointed-out that a different manufacture's brand of potassium acetate (no chemical phase diagram was provided by the manufacture/distributor) was purchased and introduced during the '98/'99 season and utilized during subsequent seasons. Initially, the truck mounted spray units sprayed this generic brand chemical product exclusively. However, with the depletion of CF7 in the FAST system's tanks, the use of this generic brand product during the '00/'01 season occurred. During a February 22, 1001 event, the application of this chemical was sprayed by the FAST system.

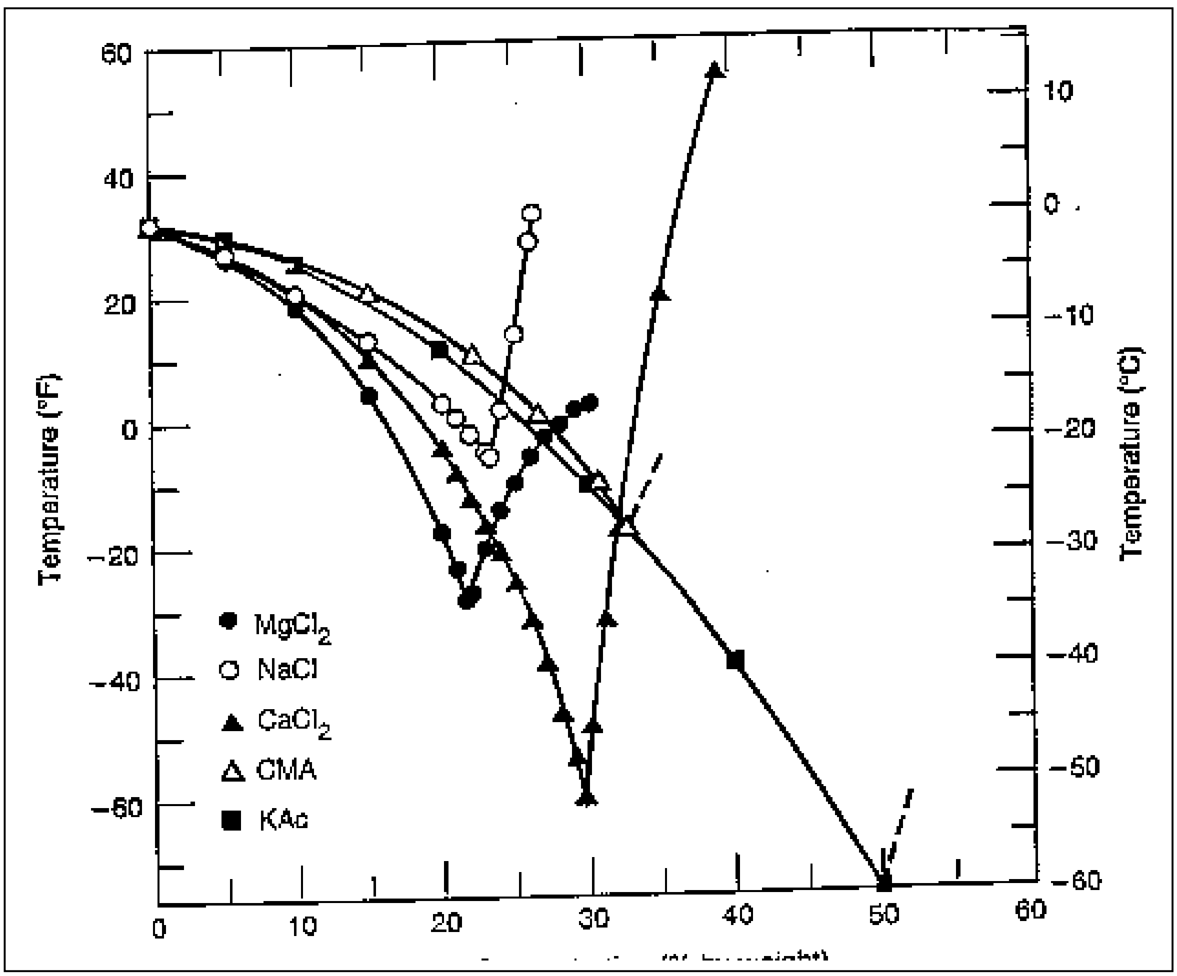



**Chart 3:** Phase Diagram [1]

It was observed that as the temperatures dropped below freezing and the snowfall precipitation rate increased, the roadway section sprayed (via FAST) with the chemical was comparatively more slippery than the adjacent sections not sprayed by the FAST system. Upon close examination of the roadway section, it was observed that the chemical – obviously diluted because of the wet pavement surface - was “freezing” on the bridge deck. Further application of this chemical utilizing the FAST system was discontinued. Test samples of the chemical were removed from the storage tanks for product analysis. The result of the analysis is forthcoming. Preliminary observations by some personnel suggest that the noticeable physical characteristics – vinegar-like odor of product, residual solution properties (slipperiness) on asphalt surfaces – were not as distinctive as the CF7.

## COST ANALYSIS

Weather scenarios in ‘98/’99 occurred that ranged from moderate snow falling with pavement temperatures rising above freezing to snow falling with pavement temperatures below freezing or expected to fall below freezing. Regardless to the condition, calling out crews too soon was a large expense incurred by the truck operation. A practice and cost that is duplicated during subsequent winter seasons (‘99/’00 and ‘00/’01).

The results of the two methods of treatments evaluated during the ‘98/’99 season suggests (see Chart 4) that the wide-scale installation of the FAST system offer the opportunity for:

- A significant return on investment;
- Significantly improves the service level on the brides roadways with the safe and rapid application of potassium acetate (CF7) to the bridges roadways; and
- Greatly reduce the frequency of decision error.

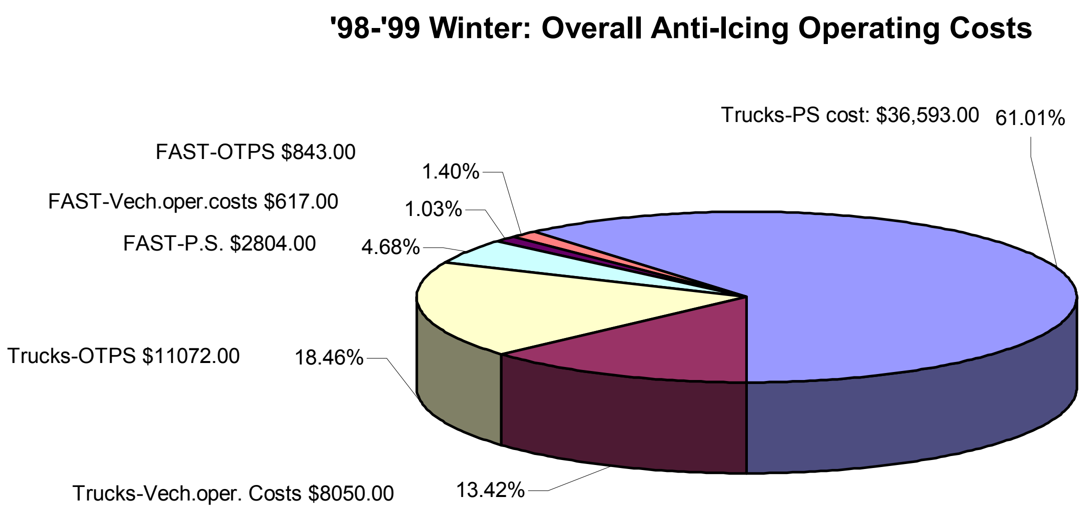



**Chart 4:** Operating Cost

## SUMMARY

### Observations and Conclusion

The homegrown development and utilization of the FAST system as part of an anti-icing evaluation program required more than bolting pipes and nozzles to the bridge and spraying the chemical onto the roadway when weather conditions deteriorated. In fact, an effective anti-icing program uses each tool as part of the larger winter road maintenance equation and decision-making process. The use and benefits of a FAST system are best optimized when the signals to activate the system are coupled with a Road Weather Information System (RWIS) that will incorporate knowledge of ambient and pavement temperatures, humidity, and precipitation type and amount. The absence of this technology in the decision-maker's toolbox has resulted in reliance on the radio, television, or in some instances, the reliance on intuition. This approach resulted in excessive and unnecessary operations expenditure totaling $8,409.00. A total of 42% of the events -responded to- did not materialized, and an additional 8% did not meet the threshold temperature recommended in the *Federal Highway Administration's Manual of Effective Anti-icing Practices* to initiate anti-icing techniques and principles.

This project verified that the FAST system can significantly and cost effectively enhance motorists safety during snow and icing conditions relative to the present over-the road (trucks) methods of application. The further development and linking of the FAST system to RWIS give winter managers added flexibility in performing their duties. Optimally, the use of the FAST systems has an inherent time advantages over calling-in maintenance crews, loading trucks, and sending them out to bridges to navigate high traffic volumes. This is especially the case in New York City[3].

The results of this investigation indicate that maintaining a bare pavement level-of-service was consistently improved by activating spray applications closest to the event start. In fact, it was noted that subsequent applications are often not required when the initial application is applied timely (the instant precipitation starts or immediately after) and rapidly. It should also be noted that in moderate to heavy snowfall (>2"), maintaining "black road" conditions is not likely without the support of a plowing operation. As an aside, during the '00/'01 winter season, two of the four significant snow events exceeded 4 inches. Plowing superseded the effective use of anti-icing. Post storm anti-icing was recommended during falling temperatures.

As illustrated by the January 14, 1999 event, a slushy-like residue (<<1") remained on the roadway that has the net effect of diluting any subsequent chemical treatments. Since plowing is generally not performed by DOS for accumulations less than (<) 2 inches, the response has been – salt the roadway. This response and action was observed on several occasions (1/8/99, 1/14/99, and 3/14/99) during the '98/'99 season. Ironically, these applications were observed being made to a roadway with "black pavement" conditions. To eliminate this response, plowing is required for snowfall ≥1 inches.

## RECOMMENDATIONS

The widespread use of anti-icing techniques, supported by the increased use of FAST systems in the Untied States is a signal being received and advanced by highway and bridge owner/managers to proactively preserve and extend the useful life of the national infrastructure. In a similar manner, the City's $2.1 billion dollars investment to rehabilitate the East River Bridges must be maximized by maintaining and utilizing proven and cost-effective methods. Part of this maintenance will be the development and use of anti-icing application techniques. Implicitly, the development and use of FAST systems during the winter months provides the greatest value to augmenting the implementation of an anti-icing program. While this method of application is not a replacement for the traditional over-the-road winter methods using trucks, it provides added flexibility and safety to the Division's winter managers.

Based primarily on the Division's 1998-1999 winter performance to implement anti-icing on the ERB, the following recommendation are listed for consideration:

- Expand and develop the FAST system on the Brooklyn Bridge. This implementation should be performed in phases. One phase will address the remainder of the South roadway; another will focus on the North roadway and a final phase would be the on-ramps and approaches.

- Initiate initial treatment application closer to the event start. This is achieved via a FAST system. Trucks will be used for plowing, subsequent treatments (if needed), and spreading of solid (granulate) deicers.

- Implement plowing operation. This task should be performed utilizing plows with slush blades[3]. This approach and strategy would have the resultant effect similar to a squeegee-like cleaning (scraping) of the roadway. This "scraping" procedure is recommended for snow accumulation < 1 inch and performed utilizing an underbody scraper.

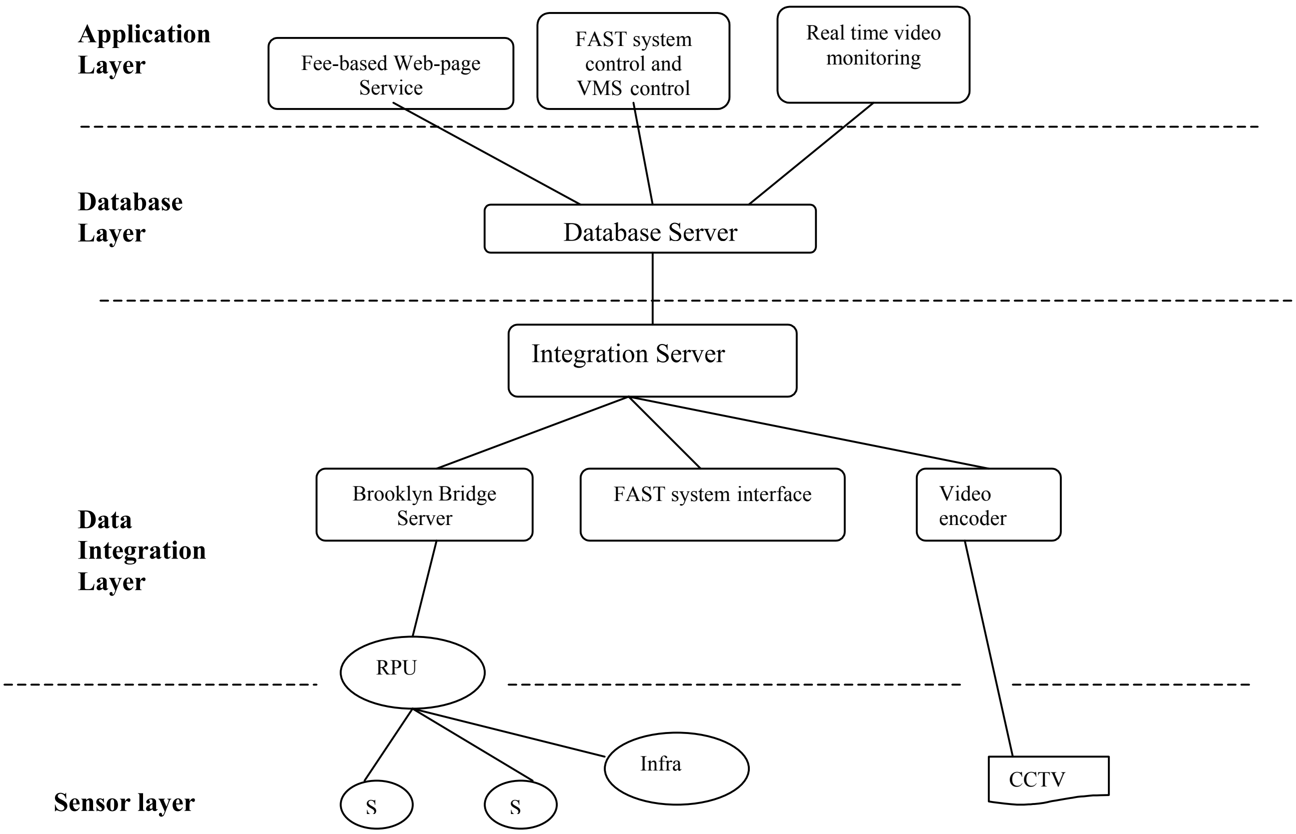
- Implement and use of a Road Weather Information System (RWIS). RWIS sensors provide a generally reliable means to monitor, detect and assist in the prediction of road temperatures and weather pavement conditions.

- Evaluate and implement the ERB Winter Incident Management Plan: Phase II

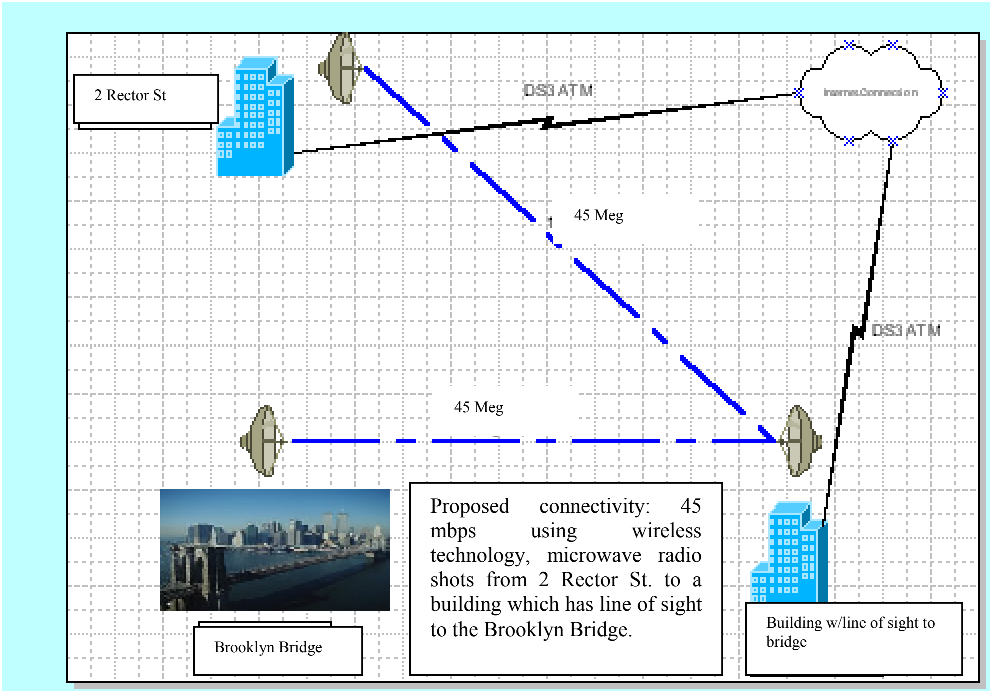
[3] A blade that uses two blades: the leading blade has a cutting edge of steel and the trailing blade having an edge of rubber.

## PHASE II: The East River Bridges Winter Incident Management

This phase of the project (phase II) describes extension of the FAST system and integration the following road weather information system's next generation (RWIS) architecture [2] model.




The demonstration phase of the phase II project shall provide for the development of proven wireless high-speed connectivity of a road weather information system's (RWIS) sensors data and distribution of real time high quality video across a virtual private IP network and IP-applications utilizing the Internet. By combining wireless technologies with a fiber infrastructure, the Division will cost-effectively link pavement sensors, non-destructive structural stress-stain sensors' data and distribute high quality live video across a Virtual Private IP network which can handle 30 JPEG images per second over the LAN and internet.




Utilizing 45 Mbps RF wireless microwave communication technologies and radio shots between two sites- Brooklyn Bridge Manhattan Tower to New York City Department of Transportation's Division of Bridges office located at 2 Rector Street in lower Manhattan-this can be accomplished.

## References

[1] Federal Highway Administration's *A Manual of Practice for an Effective Anti-icing: A Guide for Highway Winter Maintenance Personnel* June 1996

[2] Next Generation R/WIS: Concept and Prototype Implementation, Final Report-MN/RC-1999-19

[3] The Brooklyn Bridge: Fixed Anti-Icing Spray Technology, NYCDOT-January 2000 (Video file)