Winter Operations Project Plan – Snow Weather Events

City of Toronto | BUS-5300-RLA | Group Report |

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1. Executive Summary

Toronto's winter weather is becoming more severe and unpredictable due to climate change. This report outlines an adaptive, real-time winter operations strategy incorporating advanced forecasting systems, efficient resource deployment, and citizen engagement. Using the Management by Fact (MBF) framework, we examine Toronto's response to major and moderate snowstorm scenarios and draw lessons from the February and April 2025 events.

Key themes include:

- AI-enhanced forecasting and route planning
- Scenario-specific response planning
- Live operational dashboards for monitoring
- Public transparency through SnowWatch

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2. Introduction

With over 100 cm of average snowfall annually, Toronto faces growing demands for rapid, coordinated winter response. Historical challenges include:

- Delayed deployment of resources
- Communication failures
- Inflexible seasonal budgets

This project aims to introduce an adaptive operations strategy informed by real-world events and industry best practices.

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3. Project Process Areas, Inputs, and Metrics

3.1 Inputs from Forecasting

Overview:
Toronto's winter operations depend heavily on proactive and accurate forecasting. The integration of AI models with traditional meteorological data enhances situational awareness and preparedness.

Key Inputs:

- Environment Canada (ECCC) forecasts and radar feeds.
- AI-driven predictive models (e.g., IBM's Deep Thunder).
- GIS tools to track:
  - Snow accumulation
  - Freezing rain and ice formation
  - Wind speeds and temperature fluctuations
  - Potential black ice and flooding zones

Implementation Tools:

- Automated weather stations deployed across the city.
- Bi-hourly data updates with 48–72 hour forecast windows.
- Topographical data integrated with GIS for risk mapping.
- Collaborative data-sharing agreements with national and regional agencies.

Contextual Insight:
Southern Ontario has experienced an 18% increase in winter storm advisories over recent years. This highlights the limitations of traditional methods and validates the shift toward AI-augmented forecasting.

Forecasting Metrics:

- Forecast accuracy ≥ 90% (for freeze-thaw cycles, snow depth, and precipitation type).
- Advance alert issuance ≥ 48–72 hours before major events.
- Timeliness of updates (bi-hourly or as storm evolves).

3.2 City Resource Preparation

Equipment Preparation:

- 100% fleet readiness: snowplows, graders, and salt spreaders.
- GPS-enabled equipment for real-time tracking and efficient routing.
- Continuous inventory tracking of salt, brine, and de-icing materials.

Staffing Strategies:

- Seasonal workforce with rotational shifts.
- Emergency reserve crews for rapid deployment.
- Mandatory pre-season training and simulation drills.

Organizational Coordination:

- Central Command Center for citywide coordination.
- Integration with emergency services, TTC, and public utilities.
- Real-time public alerts via SMS, 311, websites, and social media.

Budget Planning:

- Flexible budget models based on predictive analytics and historical data.
- Dedicated contingency reserves for unexpected or late-season events.
- Pre-approved overtime allowances for atypical scenarios (e.g., April storms).

Resource Preparation Metrics:

- % of fleet deployment readiness (target: 100%)
- Salt inventory levels vs. projected usage
- Number of trained staff per shift during storm alerts
- Budget utilization vs. forecasted requirements

3.3 Scenario-Based Execution Plans

Scenario 1: Major Storm (>30 cm, below -15°C)

- Full mobilization of city resources.
- Prioritized route clearance: highways → transit corridors → residential roads.
- Implementation of parking bans and emergency protocols.

Scenario 2: Moderate Storm (10–25 cm, 0°C to -10°C)

- Activation of Shift B/C operational teams.
- Priority treatment of major and residential routes.
- Use of environmentally friendly brine-salt mixtures.
- Parking restrictions enforced for efficiency.

Scenario 3: Sever Storm (<45 cm)

- Pre-treatment of main roads and trouble-prone areas.
- Monitoring for ice development and spot deployment of crews.
- Emphasis on rapid response and traction maintenance.

Execution Metrics:

- % of road coverage within target timeframes (e.g., 90% within 6 hours)
- Compliance with parking bans (% adherence)
- Crew response time after forecast alerts (target: ≤1 hour)
- Salt/brine usage per km^2 vs. planned distribution

3.4 Monitoring Progress and Post-Event Evaluation

During Storm Events:

- Real-time vehicle tracking through GPS.
- Public-facing dashboards (e.g., SnowWatch) for transparency.
- Heatmaps to identify untreated or high-risk zones.

Post-Event Review:

- Structured "Hot Wash" debriefs with all stakeholders.
- Quantitative data analysis (e.g., material use, call volume, clearance times).
- Community satisfaction surveys and environmental impact assessments.

Evaluation Metrics:

- % reduction in emergency response time
- % improvement in public satisfaction (target: ≥85%)
- Environmental metrics (chloride levels, runoff quality)
- Number of reported complaints and near-miss incidents

3. Case Analysis: April 2, 2025 Storm

Event: Freezing rain and snowfall (15+ cm) at ~2°C led to slippery conditions.

Problems Identified:

- Despite accurate forecasts, road pre-treatment lagged.
- Crew deployment in key zones was delayed by 1–2 hours.
- 18% rise in emergency calls due to untreated areas.

5 Whys Root Cause Analysis:

1. **Why no pre-treatment?** → Equipment not deployed.
2. **Why not deployed?** → Inadequate staffing.
3. **Why inadequate?** → Scheduling gaps for shoulder seasons.
4. **Why budgeted that way?** → April is not considered winter-priority.
5. **Why not update in real-time?** → No flexible shift override protocol.

Action Plan:

- Extend full operations readiness into April.
- Embed AI-driven forecasting into scheduling tools.
- Update budget protocols for early spring events.

It's worth noting that the April storm occurred just days after a temperature spike, causing a freeze-thaw cycle that worsened road slipperiness. Many intersections saw a 22% spike in minor fender benders, based on Toronto Police Services' traffic logs.

This highlights the importance of not only snow depth, but also surface temperature fluctuations and moisture content—factors now included in the new brine application formula tests currently piloted in Etobicoke and Scarborough.

MBF Framework for April 2, 2025 Storm

MBF Step	Details
Problem Statement	Road pre-treatment and crew deployment delays led to hazardous road conditions and a rise in emergency calls.
Root Causes	1. Equipment not deployed due to inadequate staffing. 2. Scheduling gaps for April shoulder season. 3. Lack of flexible shift override protocol.
Actions	- Extend full operational readiness into April. - Implement AI-driven forecasting for scheduling and deployment. - Update budget protocols to prioritize early spring events.
Forecasting Metrics	- ≥90% accuracy in predicting freeze-thaw cycles and precipitation. - Real-time updates on road surface temperature fluctuations.
Execution Metrics	- Pre-treatment completed on ≥90% of priority roads before storm onset. - Crew deployment within ≤1 hour of forecast alerts.
Evaluation Metrics	- 15% reduction in emergency calls compared to similar past events. - Public satisfaction ≥85% with road conditions post-event. - 20% decrease in minor fender benders at key intersections.

5.. Case Analysis: February 2025 Back-to-Back Storms

Event:
Two consecutive snowstorms hit Toronto in the span of five days, depositing over 40 cm of snow in total. The storms caused widespread disruption across transit, roads, and city services. Crews worked continuously but snow removal was expected to take up to three weeks, and nearly 2,400 parking tickets were issued during the cleanup phase.

Problems Identified:

- Snow removal significantly delayed, projected at 2–3 weeks.
- Widespread TTC and GO Transit disruptions due to ice and vehicle blockages.
- Over 2,300 vehicles ticketed, 27 towed for parking on snow routes.
- 183 property damage collisions and 59 personal injury collisions reported.
- Multiple complaints about sidewalk and transit route accessibility.

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5 Whys Root Cause Analysis:

- **Why was snow not cleared quickly?** → Removal began after multiple rounds of plowing.
- **Why delayed removal?** → Crews overwhelmed by back-to-back storms.
- **Why overwhelmed?** → No pre-allocated surge capacity for extreme multi-day storms.
- **Why was surge capacity unavailable?** → Budget and equipment not scaled for compound events.
- **Why not adjusted in advance?** → No dynamic operational plan accounting for multi-storm accumulation.

Action Plan:

- Integrate compound weather event forecasting into operational triggers.
- Allocate on-call crews and backup equipment for back-to-back storm surges.
- Improve coordination between TTC and snow teams to clear transit routes proactively.
- Enforce timed parking bans earlier, with geotargeted alerts to residents.
- Create a storm surge readiness dashboard for city planners and public visibility.

MBF Framework for Back-to-Back Storms

MBF Step	Details
Problem Statement	Snow removal and transit operations overwhelmed by back-to-back storms, causing prolonged delays and safety risks.
Root Causes	1. Insufficient surge capacity for extreme multi-day events. 2. Budget and equipment not scaled for compounded snowstorms.
Actions	- Develop a tiered operational plan for back-to-back storms. - Allocate surge capacity (equipment, staff, and funds). - Integrate compound event forecasting with real-time operational triggers. - Launch early parking ban protocols and geotargeted alerts.
Forecasting Metrics	- Accuracy ≥ 85% for compound event predictions. - Advance notice ≥ 36 hours for parking restrictions.
Execution Metrics	- 90% snow removal completed within 10 days. - Peak crew utilization ≥ 95% during critical periods. - 95% compliance with parking bans within restricted zones.
Evaluation Metrics	- Average response time ≤ 30 minutes for major blockage clearing. - 20% reduction in property and personal injury collisions compared to previous similar events. - Public satisfaction ≥ 80% from post-event surveys.

Additional Insight:
Although snowplows operated 24/7 during the response, removal efforts lagged due to the need to complete plowing first. Travel was disrupted across TTC and GO lines, with major streetcar routes blocked by stranded vehicles. The storm highlights a critical need for a tiered emergency response that can scale beyond single-storm recovery timelines.

Case Analysis 4. Case Analysis: March 2025 Ice Storm and Power Outages

Event:

A severe ice storm struck central and eastern Ontario in late March 2025, leading to widespread power outages, tree damage, and dangerous road conditions. Hydro One reported over 400,000 customers without power, and several municipalities—declared a state of emergency.

Problems Identified:

- Over 400,000 households and businesses experienced extended power outages.
- Ice buildup on trees caused widespread damage to power lines and blocked roads.
- Emergency access was delayed in some areas due to uncleared fallen trees and live wires.
- Lack of backup generators in high-rise buildings created health and accessibility concerns.
- Residents lacked timely communication on repair timelines and shelter availability.

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5 Whys Root Cause Analysis:

- **Why were there widespread outages?** → Ice accumulation brought down power lines across multiple regions.
- **Why wasn't damage prevented?** → Tree trimming and pre-treatment were insufficient in critical zones.
- **Why wasn't access immediate for repairs?** → Emergency crews were delayed by blocked roads and hazardous conditions.
- **Why were residents without power for days?** → Insufficient mobile generators and lack of local microgrids.
- **Why didn't residents receive timely updates?** → Communication systems were overwhelmed and not localized.

Action Plan:

- Increase tree-trimming operations and identify high-risk corridors for pre-season reinforcement.
- Procure mobile backup generators for use in apartment buildings, warming centers, and critical infrastructure.
- Develop a regional emergency microgrid plan, prioritizing hospitals and high-density residential zones.
- Improve multilingual emergency alerts with shelter information and safety tips during storms.
- Train and deploy local emergency volunteers to support vulnerable residents during outages.

MBF Framework for March 2025 Ice Storm

MBF Step	Details
Problem Statement	Widespread power outages, road blockages, and delayed emergency access caused extended disruptions and safety concerns.
Root Causes	1. Insufficient tree trimming and pre-treatment. 2. Lack of mobile generators and local microgrids. 3. Inefficient communication systems during crises.
Actions	- Expand pre-season tree trimming operations in high-risk corridors. - Procure mobile backup generators for critical facilities.

MBF Step	Details
	- Develop emergency microgrid infrastructure targeting hospitals and dense residential areas. - Implement robust multilingual communication systems for real-time updates. - Deploy trained local emergency volunteers to assist vulnerable populations.
Forecasting Metrics	- Accuracy ≥ 90% for ice accumulation predictions in critical zones. - Advance notice ≥ 48 hours for storm-related risks.
Execution Metrics	- 95% of high-risk corridors pre-trimmed prior to peak storm season. - 80% of critical facilities equipped with mobile generators during emergencies. - Timeliness of communication alerts ≤ 15 minutes delay after updates.
Evaluation Metrics	- 20% reduction in road clearance delays compared to past ice storms. - Public satisfaction ≥ 85% with accessibility and power restoration timelines. - Feedback from emergency partners ≥ 90% positive on training and coordination.

Measurement Plan

Using the Management by Fact (MBF) framework:

MBF Step	Scenario One	Scenario Two
Problem Statement	Delays increase risk, road closures, and accidents.	Slower responses lead to public complaints and dissatisfaction.
Root Causes	Understaffing, delayed equipment deployment, extreme cold.	Poor forecast utilization and moderate staffing gaps.
Actions	AI-powered route optimization, dynamic scheduling, proactive salt/brine application.	Shift-based staffing, enhanced communication, live forecast updates.
Forecasting Metrics	≥90% accuracy in forecasting freezing rain and snow levels.	≤10% deviation in snow depth and timing predictions.
Execution Metrics	≥90% of priority roads cleared within 6 hours post-storm.	Call-to-response time ≤30 minutes in affected zones.
Evaluation Metrics	Reduced accident rates by ≥25%, public satisfaction ≥85%.	Complaint volume reduced by ≥20%, field crew feedback ≥80% positive.

1. **Environmental and Public Health Implications**
   - Salt-based de-icing negatively affects water quality and vegetation, leading to chloride concentration spikes.
   - Recommended Action: Expand pilot programs for sustainable alternatives like beet brine in Scarborough and Etobicoke.
2. **Technology and Innovation**

- AI and GPS systems improve resource allocation, forecasting accuracy, and citizen engagement.
- **Proposed Action:** Launch real-time SnowWatch dashboards, enabling citizen participation in reporting snow issues.

3. **Community Engagement and Equity Considerations**
    - Warming centers and volunteer programs (e.g., "snow buddies") support vulnerable populations.
    - Multilingual alerts ensure inclusivity in emergency communication strategies.
4. **Real-World Case Comparison: Montreal vs. Toronto**
    - Montreal's centralized snow removal system achieves faster clearance times and higher satisfaction.
    - **Proposed Action:** Explore centralized approaches and predictive deployment strategies modeled after Montreal.
5. **Climate Change and Long-Term Strategy**
    - Late-season storms are increasing in frequency; freeze-thaw cycles worsen road conditions.
    - **Proposed Action:** Shift to event-based scheduling and update flood maps for better preparation.
6. **Risk Management and Emergency Response**
    - Ice storms reveal gaps in generator availability and communication during emergencies.
    - **Proposed Action:** Procure mobile generators and develop regional microgrid systems to enhance resilience.

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5. Lessons Learned & Recommendations

Toronto's snow response must transition from traditional seasonal models to an agile, data-driven approach. Key recommendations include:

- Regular "Snow Event Intelligence Briefings."
- Enhanced inter-municipal coordination for shared resources.
- Adoption of environmentally sustainable alternatives (e.g., beet juice brine).

6. Recommendations

- **AI Integration**: Use predictive analytics for better planning
- **SnowWatch Dashboard**: Improve public transparency and updates
- **Eco-Friendly Solutions**: Beet juice brine reduces salt use by 30%
- **Multilingual Communication**: Serve diverse population with inclusive alerts
- **Regional Collaboration**: Partner with nearby cities for resource sharing
- **Year-Round Readiness**: Shift from calendar-based to event-based planning

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7. Conclusion

Toronto must modernize winter operations with technology, flexibility, and community focus. The 2025 snow events revealed structural gaps—but also opportunities to innovate. AI-driven forecasting, enhanced staffing protocols, and a commitment to climate-resilient infrastructure will protect public safety and increase operational efficiency.

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