FINAL PROJECT: A WEATHER-AWARE ROUTING AND MONITORING DASHBOARD FOR CANADIAN GROUND LOGISTICS

DATA*6200 - FALL 2025

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Shifting road conditions due to weather can create challenges for any driver, but for ground transportation fleet dispatchers and owner-operators unanticipated weather delays can mean lost revenue, lost reputation, and increased risk. Proactively anticipating adverse conditions at the local, regional, and provincial level is critical to their ongoing success.

This dashboard was created as a tool for those ground logistics professionals and comes equipped with several key features that can be used to ensure the job gets done right.

Motivation

Our dashboard is designed to streamline the workflow of ground logistics dispatchers and enable them to make better routing decisions. Delays cost money – if the pay structure is by the mile, truckers absorb the loss, but if it's hourly, the firm does. Either way, they should be avoided.

Normal routing apps (Google Maps, Waze) focus on traffic, which is problematic for trucks for two reasons. The first is that most cars drive significantly faster than most trucks because trucks have legally mandated speed limiters (Ontario to limit truck speed, 2008). When ordinary drivers are delayed, they can go over the speed limit to compensate, trucks can't. The second is that weather conditions affect trucks more significantly than traffic. While most navigation systems focus on traffic, ours focuses on weather. The primary benefit is that traffic does not require trucks to slow down as dramatically as weather does. There is rarely an alternative route that has dramatically less traffic, as the widespread adoption of navigation systems like Waze and Google Maps reroute traffic to the less-used route. It is, however, significantly more feasible to avoid driving through storms and uncleared roads.

To give an idea of the magnitude of slowdowns, uncleared snow requires a speed reduction of 50% (CMV Driving Tips - Too Fast for Conditions, 2015) according to FMCSA. Although this is an American body, we chose to use their recommendations as they are clearly being mirrored in the Canadian industry (Truck Driving in bad weather, 2025), and the official Ontario guidelines are comparatively vague (Driving at night and in bad weather, 2022). These rules are used to modify the costs associated with traveling a given stretch of road for our routing algorithm.

Herein lies the core benefit of our system: it is a lot easier to avoid a significant delay when the choice is between a lightly snowed-on road with a 70 km/h recommended speed and a snow-packed road with a 50 km/h recommended speed, vs. a 400-series highway going 60 km/h in rush hour and a secondary highway going 70 km/h in a less direct route. Because dispatchers using our system are accommodating for weather, there is less pressure on drivers to overlook safety to reach their destination on time. In theory, this means that over time insurers would penalize logistics companies not using a similar system due to more frequent accidents.

The business case for adoption is quite simple. In order to make an economic profit (profit in excess of the next best option), firms need market power. Some industries are pure monopolies, like Hydro One, others are perfectly competitive like landscaping, but most exist in the in-between state of monopolistic competition. Using the Cournot model of monopolistic competition where firms compete on quantity rather than price, cutting production costs means a firm can produce more at a given price point which in turn forces their competitors to produce less to maintain profitability. If our system results in more trips per truck per year, and lower than average insurance premiums per truck, that would mean that the cost to produce the service has gone down.

Our app aims to provide trucking companies that adopt it with greater profits, the wider economy with cheaper ground logistics, and drivers of all kinds with safer roads.

Design

Home page

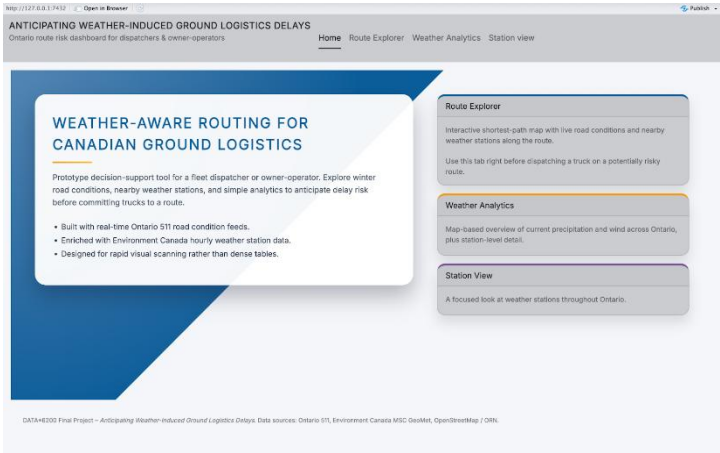

Figure 1

The **Home** *(Fig. 1)* page is a landing screen that explains the purpose of this app in a single card ("Weather-aware routing for Canadian ground logistics") and gives three large navigation cards for the key features. Each card briefly describes what the corresponding tab does (Route Explorer, Weather Analytics, Station View) and is clickable. This means a dispatcher who opens the app for the first time does not have to guess where to click, if they want to plan a trip they click "Route Explorer" or if they want a general overview, they choose "Weather Analytics" tab. The hero text also reassures users that the app is powered by live road condition feeds and hourly weather data, so they know it is suitable for daily operational decisions.

Route Explorer: route-centric risk check

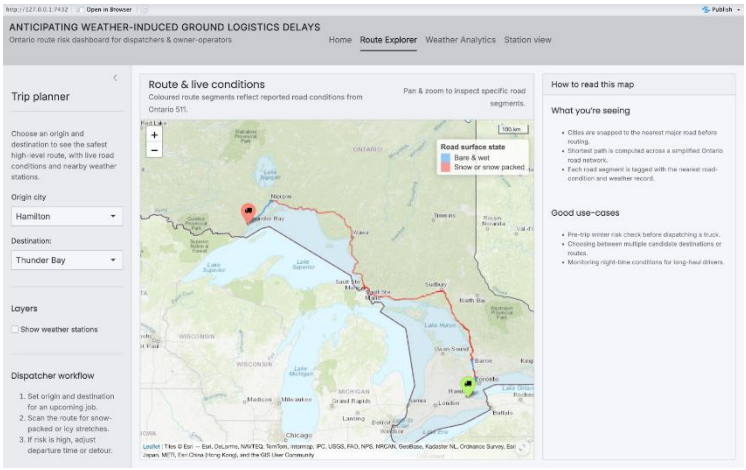

Figure 2

The **Route Explorer** *(Fig. 2)* tab is the main operational view. On the left, a "Trip planner" sidebar lets the user choose an origin city and a destination from dropdown lists. Once both are selected, the app calculates a shortest route across a simplified Ontario road network but also adjusts travel times based on the reported surface state (for example, snow-packed or icy roads are treated as slower). The resulting path is drawn on the map with each segment coloured by its current road condition (bare, wet, partly snow covered, snow or snow packed, icy). A legend on the map explains the colours(red, blue, etc) depending on the situation.

For a dispatcher, this makes it easy to scan the entire route and immediately see where the risky segments are, instead of reading a long table of condition codes. A checkbox allows the user to overlay nearby weather stations along the route; clicking a marker shows temperature, precipitation and wind chill at that point. This is useful when deciding whether to delay a departure, add extra time to the schedule or reroute around a corridor that looks consistently bad. On the right, a small “How to read this map” panel explains in plain language what the user is seeing and suggests good use-cases (pre-trip winter risk check, comparing candidate routes, monitoring night-time conditions), so the page is self-documented.

Weather Analytics: province-wide picture on one screen

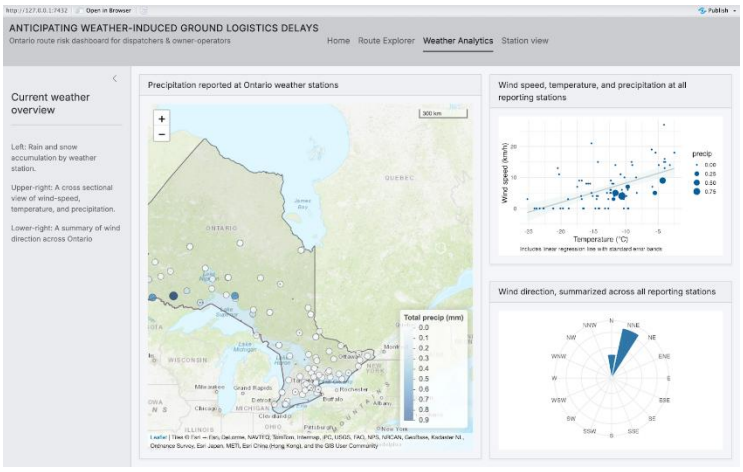

Figure 3

The **Weather Analytics** *(Fig. 3)* tab shifts from a route view to an Ontario-wide overview. The large map on the left shows all reporting weather stations as circles whose size and colour reflect recent precipitation. This acts as a quick “heatmap” of where rain or snow is currently concentrated. A manager can use this to decide, for example, that loads heading into an area with widespread high precipitation should be deprioritised or given extra time.

On the right, two compact plots summarise the broader weather pattern. The first is a scatterplot of wind speed versus temperature for all stations, with point size indicating precipitation; this gives a cross-sectional view of how windy and cold the province is overall, and helps identify whether today’s conditions are benign or hostile overall. The second plot is a wind rose that counts how many stations are reporting wind from each direction. This is helpful when thinking about crosswinds on long, exposed highways. Short explanatory text in the sidebar describes what each visual shows, so non-technical users can still interpret the charts correctly.

Station View: deep dive on a single location

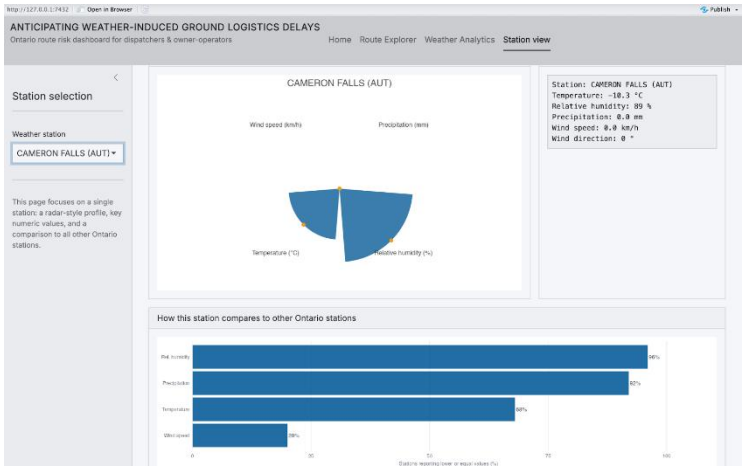

Figure 4

The **Station View** *(Fig. 4)* tab focuses on one weather station at a time. The user selects a station from a dropdown provided on the left, the rest of the page updates automatically. The main plot is a polar (radar) chart that shows temperature, precipitation, wind speed and relative humidity for that station, scaled relative to all other Ontario stations. At a glance, the user can see whether the station is unusually wet, windy, cold or humid compared to the rest of the province.

To the right of the radar plot, a small text box lists the key numeric values (temperature, humidity, precipitation, wind speed and wind direction). Below, a horizontal bar chart shows the percentile of this station for each metric (for example, “Precipitation: 92% of stations are reporting lower or equal values”, as shown in the figure). Together, these views let a dispatcher justify operational decisions such as “conditions at our depot are worse than almost anywhere else in Ontario right now, so we expect delays” without needing to dig into raw data. The sidebar description reinforces that this page is meant for station level monitoring and comparison.

Under the hood: A reactive approach using R shiny

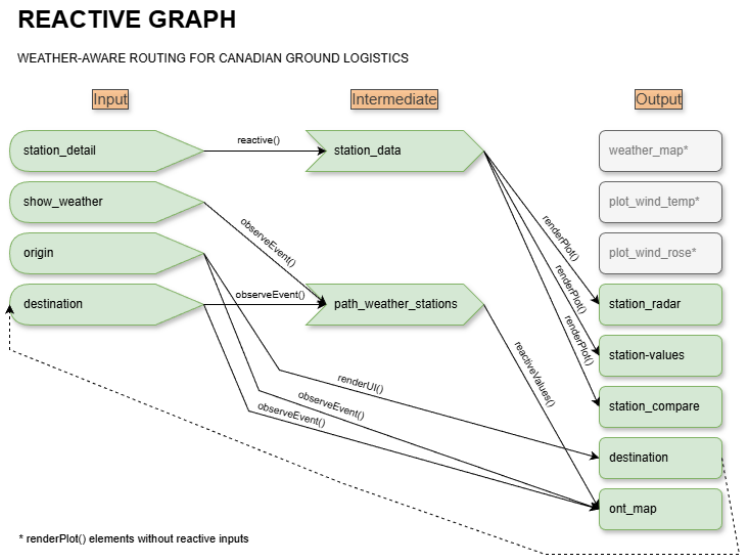

Figure 5

The dashboard is powered by the R programming language and leverages the shiny package to create an interactive and engaging user-facing application. These tools, working in tandem, allow the creation of powerful statistical and data manipulation applications that are readily accessible for many users.

A cornerstone of the synergy between R and shiny is the reactive framework. This framework allows developers to succinctly identify what interactive elements need to be updated, when they need to be updated, the scope they need to be updated within, and what downstream effects their update should have. This allows smooth dashboard performance, controlled resource management, and deep interactivity. These relationships can also be visualized for analysis and training using a reactive graph *(Fig. 5)*.

Design choices that support the user

Across all pages, the app uses a consistent visual theme (colours, fonts, card layout) and relies on maps as the main way of interacting with the data. Controls are simple and focused on the task (choose cities, tick a box, pick a station), each tab has short helper text that explains how it should be used in practice. This combination of real-time road and weather feeds with a clear, map-based interface allows logistics managers and drivers to take concrete decisions such as whether to dispatch, delay or reroute a truck without needing to understand any of the underlying modelling.

Limitations

Defining the scope of a project inherently sets certain limitations on what can be done with the resulting tool, and these decisions can impact the way that users can interact with it.

The functional space of the tool is within the Ontario provincial borders, so users needing to extend their trip outside of Ontario would only be able to plan a portion of their trip using this tool.

The origin and destination cities are restricted to cities in Ontario with a population of 50,000 or more. This creates a challenge for users targeting smaller cities. Making use of the Route Explorer tool would require them to identify a nearby city of 50,000 or more, plot a route using that city as an origin or destination, and then manually integrate the Route Explorer feedback with their own independent planning.

In that same vein, the exact origin or destination point within cities often represents a central location like downtown or city hall. In reality these locations could be several kilometers from the target address, meaning users would need to coordinate last-mile navigation independently. This sort of precise point-to-point navigation is intentionally outside of the scope and intent of this dashboard, but it is important to acknowledge it as a limitation so users understand what is and is not possible with the application.

Also outside of the scope of this app is local street navigation. Due to both the intent of the app and the technical limitations associated with storing data on the numerous local streets in Ontario, the navigation process is limited to larger roadways. Users should be aware of this limitation and have a plan in place to manage last-mile navigation.

Not all limitations are due to scope decisions. Some technical aspects of the dashboard are also limiting factors and need to be discussed. First among them is the handling of large amounts of data. The dashboard sources data from 3 local and 2 api-driven data sets, capturing millions of data points. That data has been refined and condensed but still requires considerable hardware overhead.

One of the most visible ways that this limits the application is in the initial load time. From the time the user initializes the application, it can take several minutes for the dashboard to load, download, format, and model the data. Once this process is complete the app generally works smoothly but the user should be aware that, in its current form, the application requires some lead time.

Relatedly, the route discovery aspect of the Route Explorer tool takes a small amount of time to process. It uses a pre-compiled network map of all the roads in Ontario and processes the network routes using a Dijkstra pathfinding algorithm with custom-modeled

weights. This calculation takes a small amount of time to execute and user expectations should be set accordingly.

Lastly among the most noticeable app limitations is the possibility of stale data as the work session continues. Up-to-date data is downloaded once at the start of a work session, and there currently is no in-app method for updating the data after that. Users in need of more frequently updated data should make time in their workday to reload the system to refresh the data.

Improvements

Some of the issues recognized in the limitations section could be resolved or mitigated with future updates. At the top of the list might be functionality that periodically downloads updated data from the dashboard's live-data services like Ontario 511, ensuring the user always has access to current conditions. If technical limitations prevented a streamed-data approach, a button with "update data" functionality could be implemented for easier manual update.

Techniques for improving the performance of the pathfinding could also be examined. Using a bounding box to filter the roads available for pathfinding could result in significant performance improvements, but it would have to be carefully crafted to ensure it was not eliminating potential routes in the process. In deciding not to implement this feature we have recognized that this is a challenging task, and chosen to err on the side of completeness and precision rather than performance.

Depth and breadth expansion is also possible. It would only be logical to expand the app functionality outside of Ontario, and to also include smaller cities and roads in the navigation options. As discussed, these features come with overhead costs, and we would need to ensure that this expansion could be undertaken without sacrificing the core functionality of the app.

There is also room for new features in the dashboard. Features like textual turn-by-turn navigation instructions, multi-route comparison, and user-tunable routing weights all seem like challenging but achievable features that would add real value for end users.

The addition of more interactive metrics and statistical displays could also be valuable for users, but we feel that it would be important to get feedback from subject matter experts before doing so. Adding dashboard elements that don't improve the user experience would add clutter and make it harder to onboard new users, for very little added value. Informed users would be able to guide this process and help us understand what is most useful, what is missing, what should be improved, and what should be dropped.

Summary

Over the road transportation can be a challenging and dangerous occupation, and a lack of insight into road conditions between a driver and their destination only exacerbates those challenges. It is our hope that this app empowers the decision-making and workflow of dispatchers and owner-operators, and leads to tangible improvements in profit margin, safety, and reliability.

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