Least Cost Path Modeling for a Proposed LRT Route in the HRM

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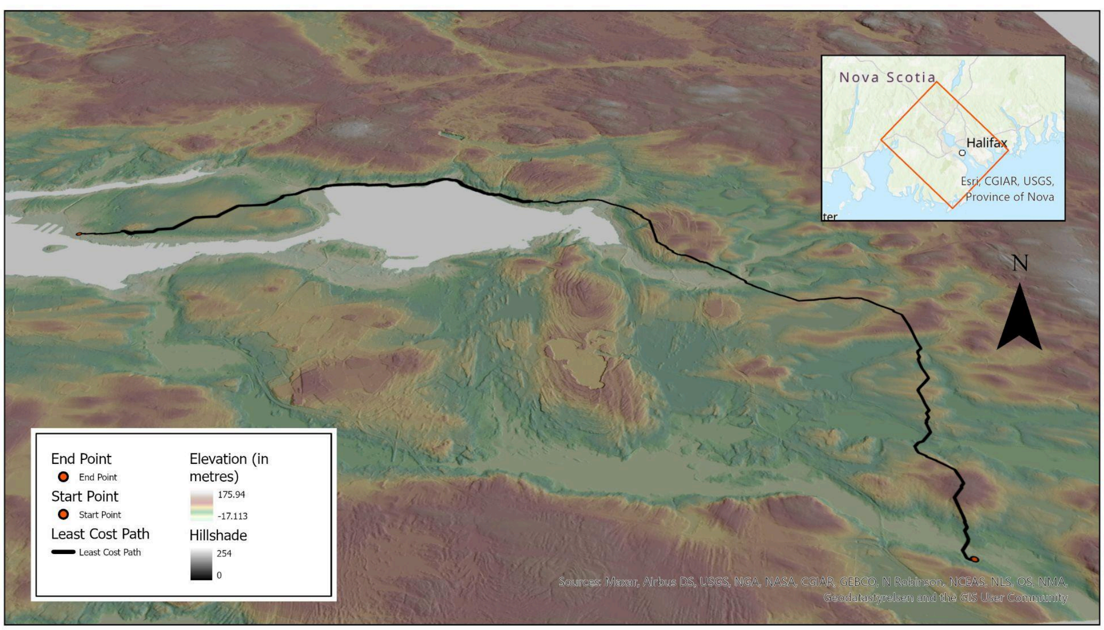
I. Background and Rationale for Project

This analysis used geospatial methods to evaluate a proposed light rail commuter line for the Halifax Regional Municipality (HRM). Recent transit planning in Halifax is driven by three key factors: public demand, government funding, and a rapidly growing population. Only 35% of respondents in the 2024 Halifax Residential Survey (HRS) were satisfied with the state of public transit (Narrative Research 2025, 75). Despite this fact, 62% of residents still use transit. Residents suggested that increasing reliable service, frequent service and direct routes would increase public transit use (Narrative Research 2025, 76-77). Beyond current local demand, future demand for expanded transit will increase because Halifax is experiencing record high population growth. The growth rate rose to 4.1% between 2022 and 2023, with over 19,000 new residents entering the city that year (Halifax Partnership 2024). In light of recent population



The Least Cost Path for a Proposed Light Rail Transit (LRT) Route for the Halifax Regional Municipality (HRM)

By Emily Hesp

Sources: C. Cunningham 2025, Statistics Canada 2021, CHASS 2021, HRM Open Data Halifax Regional Municipality 2025, Nova Scotia Forest Inventory 2025, Nova Scotia Topographic Database 2024.

trends, a federal investment of 55 million dollars will be allocated to Halifax for the long-term maintenance of its transit systems under the Canada Public Transit Fund (CPTF). The Mayor of Halifax is confident that this long term transit investment will create a "thriving, sustainable and inclusive city" (Housing, Infrastructure, and Communities Canada 2025). This outpouring of public and governmental support for improved public transit shows that the LRT proposal was a timely response to the inadequacies of regional transit quality and access.

For this project, the HRM commissioned a geospatial model of a proposed light rail line (LRT). A least cost path (LCP) analysis was used to model the path for the new LRT line. This line will connect the suburban/peri-urban fringe to the downtown train station. The proponent identified five categories and criteria for the LCP analysis. The categories include lakes, swamps, commuter data, rivers and slopes. The LCP analysis identifies the path upon which costs, such as proximity to undesirable features, are minimized according to the raster value classifications in impedance surfaces. Impedance surfaces define what values are costly according to the criteria specified for the analysis. For example, in this analysis, raster cells containing low values of commuter counts would be less desirable and were assigned a value of 2000 to signal that costliness to the GISystem. The impedance surfaces will be combined to create a cost surface for all criteria, and used in combination with other GISystem analysis tools to identify a path that would be the most suitable for a new LRT line.

II. Proponent's Proposed Analysis

I started my Least Cost Path Analysis by converting all layers to a common spatial reference system, the NAD1983 UTM Zone 20N projection. From there, I extracted Start Point 2 from the Start Point layer and exported the feature class. I then used the summarize fields tool to identify the relevant feature classes in the WaterAreal polygon layer. I then conducted an attribute selection query for each relevant class of water polygon (i.e. lakes, rivers, swamps) and exported the features for each category. From there, the count of drivers and count of passengers from the census table was summed using the calculate field tool to create a new field called "Commuters." This field was joined to the dissemination areas (DA). This layer was then rasterized to create raster values that could be reclassified for the Commuter criterion. All data layers were then clipped (ex. clip for vector, extract by mask for raster) to the study area and the old data layers were removed from the map.

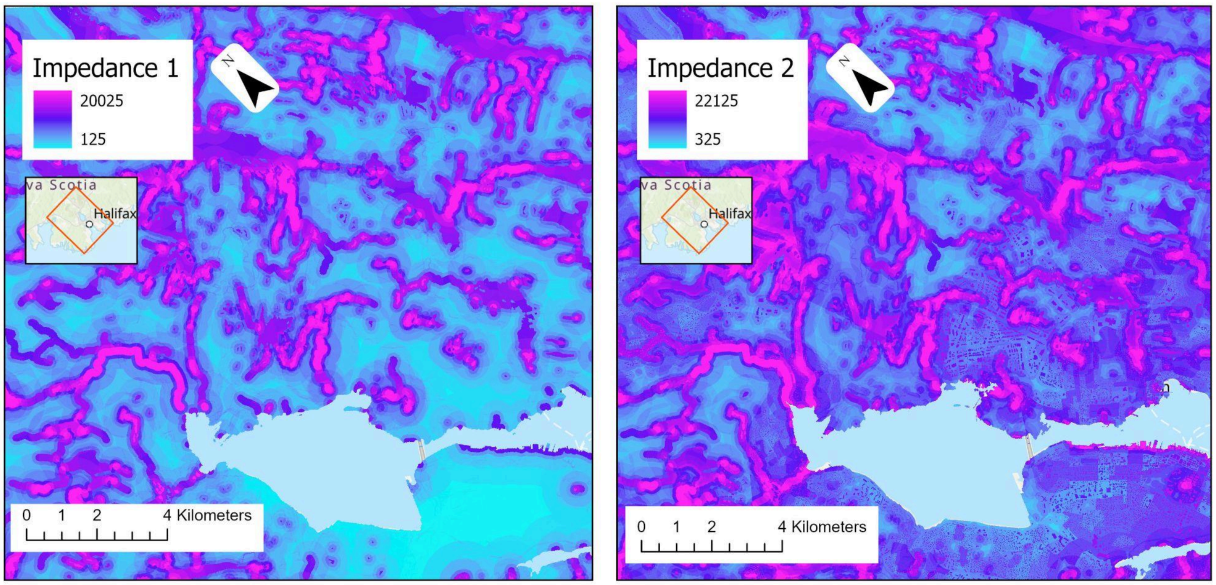
Before I created the impedance layers, I made sure to edit the analysis environment so that the Processing Extent, Snap Raster and Cell Size to be consistent with the elevation layer. This was key to ensuring that the spatial resolution of the impedance raster was 10 x 10 metres. Next, a batch distance accumulation operation was applied to all the categories with a distance criteria (i.e. swamps, rivers, lakes, river polylines) to make their respective impedance surfaces. The polygon to raster tool was used to convert the dissemination area polygons to raster data. This was done so that the commuter values could be reclassified according to the proponent's criteria. I then produced a slope surface in percent rise, using the DEM elevation layer as the input raster. Next, the values in the swamp, lakes, commuters/DA, rivers, river polylines layers were all reclassified individually according to the criteria outlined by the proponent. Lastly, I created a constraint surface to constrain the final impedance surface to the land portion of the study area. All land areas were reclassified as 1 and ocean regions were assigned a value of "No Data." All five impedance layers were then combined to create the final impedance layer.

To create the Least Cost Path, the impedance layer and start point were inserted in the Cost Distance tool, which created a Cost Distance surface and the Backlink raster. These two layers were then used in combination with the end point in the Cost Path tool to create the output raster of the LCP. From there, the Raster to Polyline tool was used to turn the LCP into a vector polyline layer so that I could increase the visibility of the LCP symbology. A hillshade was then created using the DEM elevation layer. This layer was placed behind the elevation layer. The elevation layer was changed to have a hypsometric colour scheme and a minimum-maximum stretch type. Resolution was 70 percent. Finally, I added the start point, hillshade, elevation layer, end point and least cost path to the final map layout, alongside map elements.

III. Expanded Analysis

For an expanded analysis, I included distance from building polygons as an additional category for my LCP analysis. This criteria merits inclusion because the impedance layer would identify lesser developed areas as less costly. Constructing a LRT along this path would allow for future developments of Transit Oriented Communities (TOCs). Considering future development is important because the HRM has a goal of doubling its population by 2050 (Moore, 2024). To accomplish this, infrastructural and housing solutions must be planned to ensure that new residential areas are accessible and thriving in the long-run. Coupling mixed-use buildings with proximity to essential services, like transit, allows people to live more affordable, well-rounded and active lifestyles. Creating TOCs is the broader goal that all federal investments under the CPTF are aimed at accomplishing (Canada, 2024). To allow for further growth and development, the LCP for the proposed LRT should be constructed in areas with fewer pre-existing buildings. Mixed-use TOCs should be constructed along the LRT line so that the inbound and outbound transit capacity gets enough use to remain viable while also addressing the need for an increase in regional housing supply (Martin 2024). Therefore, distance from building polygons should be factored into this Least Cost Path analysis.

Comparison of Impedance Surfaces



Map 1: Impedance Surface Based on the Proponent's Criteria

Map 2: Impedance Surface of the Expanded Analysis (incl. buildings)

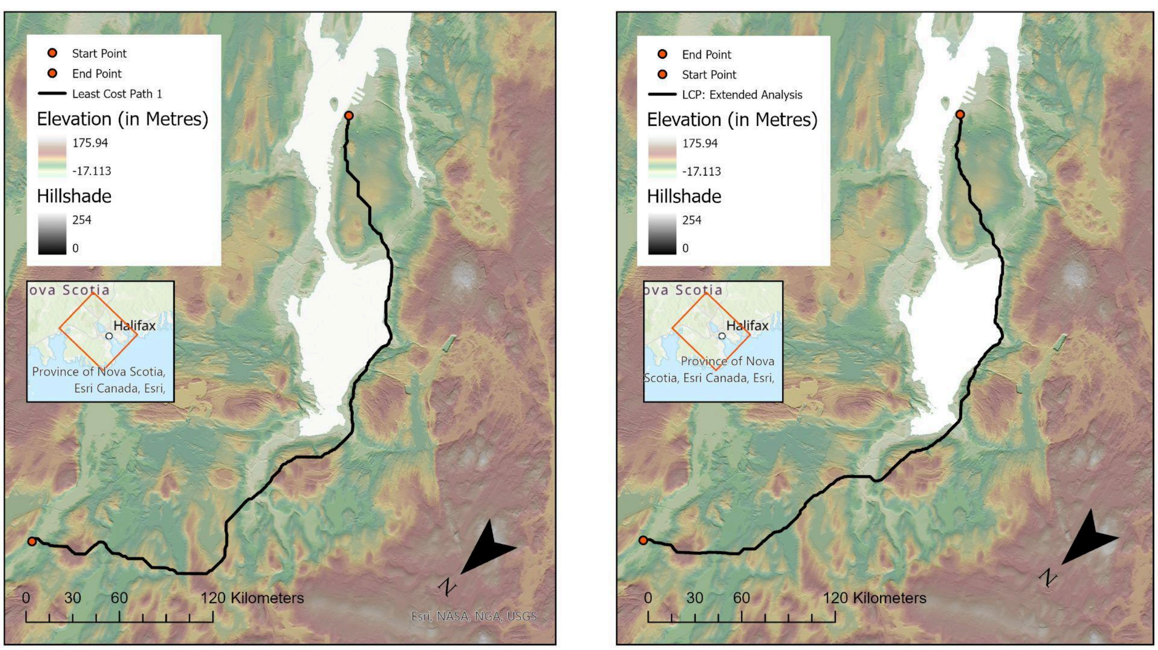
By Emily Hesp

Data Sources: C. Cunningham 2025, Statistics Canada 2021, CHASS 2021, HRM Open Data Halifax Regional Municipality 2025, Nova Scotia Forest Inventory 2025, Nova Scotia Topographic Database 2024, Basemap: Esri 2025.

Basemap Sources:
Esri, NASA, NGA, USGS, Province of Nova Scotia, Esri Canada, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, NRCan, Parks Canada, Province of Nova Scotia, Esri Canada, Esri, TomTom, Garmin, FAO, NOAA, USGS, NRCan, Parks Canada, Esri, USGS, 2025.

For this expanded analysis, my criteria for the building polygons required that the LCP minimized the path running adjacent to areas with more buildings and did not cross buildings. Raster values were reclassified accordingly, with 0 values (that represent the buildings) being extremely undesirable (i.e. high cost) and values over 1000 being ideal (i.e. low cost). To conduct the analysis, the previously made constraint surface, the building polygon layer, the elevation layer, hillshade, start point, end point, impedance surfaces for the lakes, rivers, river polylines, slope, commuters and swamps were loaded into the map pane. The building polygon layer was rasterized using the polygon to raster tool and then processed using the distance accumulation spatial analysis tool. Following this calculation, the values were reclassified according to the specified criteria. Ranges of values indicating closer proximity to buildings were

Comparison of LCP Analyses for the proposed HRM LRT



Map 1: LCP of the Proponent's Criteria   Map 2: LCP of the Expanded Analysis

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reclassified as high cost (i.e. 1000-5000) and other ranges of values indicating further distances from buildings were reclassified as low cost (i.e. 500-25). A total of six ranges of values were used to reclassify the building raster values for the new impedance layer. From this point, all impedance layers were summed in the raster calculator and multiplied by the constraint surface to create the final impedance layer. This layer was then used to create the cost distance surface and the backlink surface. These two surfaces were then used to generate the Cost Path. The cost path was put into the raster to polyline tool. Symbology was edited for the end point, start point and LCP to increase visibility of the features. For the final map product, the elevation layer, new LCP, start point, end point, and hillshade were loaded into a new map. A map frame of the new map was added to a new layout alongside the proponent's original LCP map.

IV. Discussion

The proponent's requested approach was appropriate for assessing the cost of environmental and demand based factors. In the outlined criteria, it is worth noting that no values were assigned "NODATA" when reclassified. This reflected the fact that the proponent requested that the modelling "try NOT to cross" water bodies and "minimize" the path running adjacent to water bodies. If "NODATA" was used in the reclassification of values, then water bodies would be avoided completely by the Cost Path tool. Instead, raster cells with 0 values were assigned a value of 5000 to indicate that areas with swamps or lakes were "extremely undesirable." With reference to Map 1 of the Comparison of Impedance Surfaces, there are many high cost areas and much of them are concentrated around the water features. The proliferation of water features is also evident by the shape of the high cost areas. They are shaped like water bodies. If these areas were avoided completely by the LCP, then distance traveled would increase dramatically and make the cost of travel time unreasonable for its riders. Efficiency must be prioritized in combination with environmental considerations for the LRT to be viable. Therefore, using a higher cost value instead of NODATA would minimize both travel distance and water body proximity. Another strength of the analysis was that the number of commuters in each raster cell was accounted for, with higher levels of commuters being reclassified as more desirable and lower levels as less desirable. This is important to determine whether there would be enough commuters that would switch from car travel to public transit. This would be important to determine whether this transit project would help the city meet its climate targets, since popular use of public transit is better for the environment than car travel (Canada 2024).

As shown in the Comparison of LCP analyses, the LCP of the expanded analysis is relatively consistent with the Proponent's LCP until it departs from the shoreline. From there, it curves inward to the east where the Proponent's LCP curves outward to the west. This could mean that even though areas along the shoreline might be more developed, other factors such as a high density of commuters or less slope could make the shoreline area less costly to construct the LRT line along. However, the map of the expanded analysis would be the best LCP analysis to present to the public for feedback because the proximity to buildings must be considered when accounting for the long-term viability of transit. While it may be beneficial to service areas that are already densely populated, the city is planning for its future. Currently, this city plans to double its population (Moore 2024). Housing supply and access to other essential services must be planned accordingly with population growth in mind. It would be more beneficial to future and current residents if the city plans the LRT so that it passes through areas that have more space for future development. A point of contention may be whether it is prudent to build transit in anticipation of building development. However, an Ottawa city councillor argues that the inverse could be worse. Steve Deroches said that high rise residential towers were constructed in anticipation of a LRT link in Chapman Mills. Ultimately, the plan was cancelled, which was a “step backwards” for that community (Crawford 2024). Deroches goes on to say that transit oriented development is key to attracting densification and ensuring that new housing development stays accessible. Therefore, it is important that the proposed LRT for the HRM crosses through areas with less pre-existing buildings, so that new Transit Oriented Communities can develop and support the anticipated influx of new Halifax residents.

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