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Index of Remoteness 2021: Update with 2021 census geographies and populations

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Introduction

This report provides information regarding the update that was done to the Statistics Canada Index of Remoteness. The Index of Remoteness was first compiled using the 2011 census of geographies and populations followed by an update in August 2018 with the 2016 census of geographies and populations. A report explaining the motivation and methodology for the index was published on May 9th, 2017 (Alasia et al., 2017). With the release of 2021 census geographies and populations, Statistics Canada updated the Index of Remoteness.

This report explains the steps and process that were undertaken to update the Index of Remoteness with the 2021 census geographies and populations. The report also provides a short analysis of the 2021 results as well as a small exploration of the changes in the remoteness measure over the last two periods.

Technical Notes

The following section explains the steps that were taken to update the Index of Remoteness with the 2021 census geographies and populations.

Updating Geographies and Populations

The two primary geographic units of analysis of the Index of Remoteness are the Census Subdivision (CSD) and Population Centre (PopCtr) geographical units. Table 1 shows the number of new and disappearing CSDs and PopCtrs between 2016 and 2021.

Table 1
New and disappearing Census Subdivisions and Population Centres

Province/Territory	CSDs 2016	CSDs 2021	PopCtrs 2016	PopCtrs 2021
Total	5162	5161	1005	1026
New	...	141	...	50
Exiting	...	142	...	29
Common	...	5020	...	976

... not applicable

Source: Authors' computation.

Population numbers used to update the Index of Remoteness come from the 2021 census (Statistics Canada, 2022).

Updating Rates for Travel Cost

In addition to the CSD and PopCtrs, the 2021 Index of Remoteness update also included updating the travel costs rates used for estimating the CSD-PopCtr travel cost matrix.

Connected CSDs

CSD-PopCtrs travel distances for the CSDs accessible by road or regular ferry were converted into travel costs using data from the Canadian Automotive Association (CAA), amongst other information.

The 2016 CAA Driving Cost was estimated to be 16.0 cents per kilometre. The 2016 per kilometer operating cost was estimated after applying the annual Consumer Price Index (CPI) for "Operation of passenger vehicles" adjustment (2013 and 2017) to the reported 2013 CAA Driving Costs for operating a mid-sized vehicle driven 18,000 km per year. The 2021 driving cost per kilometer was estimated using the CAA driving cost calculator.[1]

The CAA operating cost of a new 2021 mid-sized vehicle[2] being driven 20,000 km per year was estimated to be 0.1782 dollars per kilometer. The methods used to update the cost of driving took into account the updated operating costs provided by CAA and price variations reflected in selected Consumer Price Index (CPI) components. This resulted in an estimated cost of 0.18 dollars. Hence, 18.00 cents per kilometre is what was used to calculate the CSD-PopCtr travel cost matrix for the CSDs accessible by road or ferry.

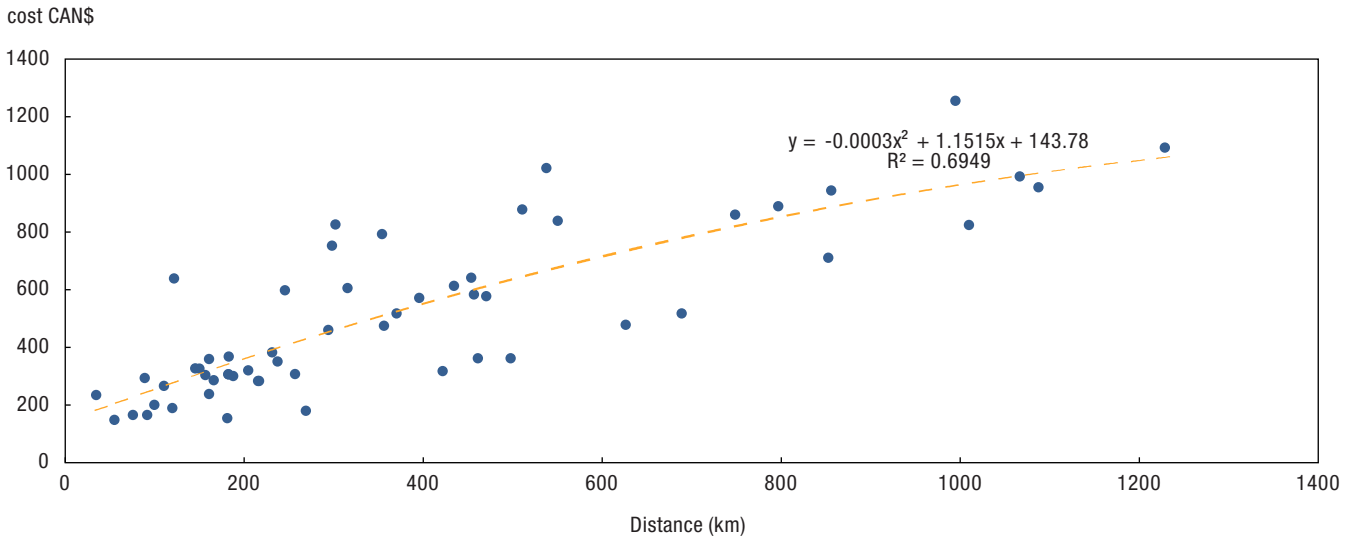
For CSDs that are themselves population centres, the size of their own populations is included in the calculation. When locations of two representative points are very close or overlap, a travel cost of $3 is assigned and is assumed to be the minimum cost of transportation. Condition “c” in equation (1) below captures this case.

Non-connected CSDs

For non-connected CSDs with a population greater than zero, and who are not themselves population centres, research on the web was performed to obtain cost estimates for traveling to the most accessible (minimum cost[3]) population centre.[4] The costs retrieved were for one adult traveling one way with the cheapest fare option. For seasonal ferries, or boat/water taxis, the distance of the ferry route multiplied by the CAA operating cost of 0.18 dollars per kilometer was used to estimate the ferry travel cost.[5] For a small number of communities (29 out of 86), travel by air does not follow a regular schedule and must be chartered.[6] Prices for such travel options are not available online. For these cases, and like was done for the 2016 Index of Remoteness, a regression model was used to convert linear distance (*x)* to travel costs (*y*). The regression model was estimated based on the data for 57 non-connected[7] communities where one-way direct air travel costs to the closest population centre were obtained. The results of the model are shown in Figure 1, using September 2022 flight costs the model specification is $y = 144.78 + 1.1515x - 0.0003x^2$. For unconnected CSDs that require air and a combination of transportation infrastructure to reach the nearest population centre flight costs were imputed using the model in Figure 1 between aerodromes and/or seaplane bases. It is important to note that if a CSD was unconnected in 2016 and connected in 2021 only the connected travel cost would be used to calculate the 2021 Index of Remoteness.[8] This excludes CSDs that are only connected to the main road/ferry network via a seasonal ferry or winter road’ in the majority of these cases, direct or indirect (for a combination of transportation infrastructure types used) flight costs were used instead of driving only travel costs. In addition, for unconnected CSDs reporting a population but with no transit infrastructure at the CSD representative point no Index of Remoteness was calculated; these CSDs were labelled as “no infrastructure” for transportation infrastructure.[9]

2 A new 2021 Ontario Honda Accord SE 4D Sedan driving 20,000 km per year was used for this estimate. A comparison to other provinces and mid-sized cars estimated similar operating costs per kilometer.

Figure 1
Scatter plot of cost ($) and linear distance (km) for traveling by air (September 2022)



Note: The model used for the 2016 version of the Index of Remoteness included a quadratic term for distance. This term was included in the 2021 version for consistency.
Source: Authors' computation.

CSDs Reporting No Population

CSDs reporting no population were treated in two ways. CSDs connected to the main road/ferry network and having access to at least one PopCtr were treated as described in the section above on "Connected CSDs".[10] For CSDs reporting no population and being unconnected, no travel costs were calculated. For CSDs having a population and identified as having no transportation infrastructure in the CSD, no travel costs and consequently, no indices were calculated.

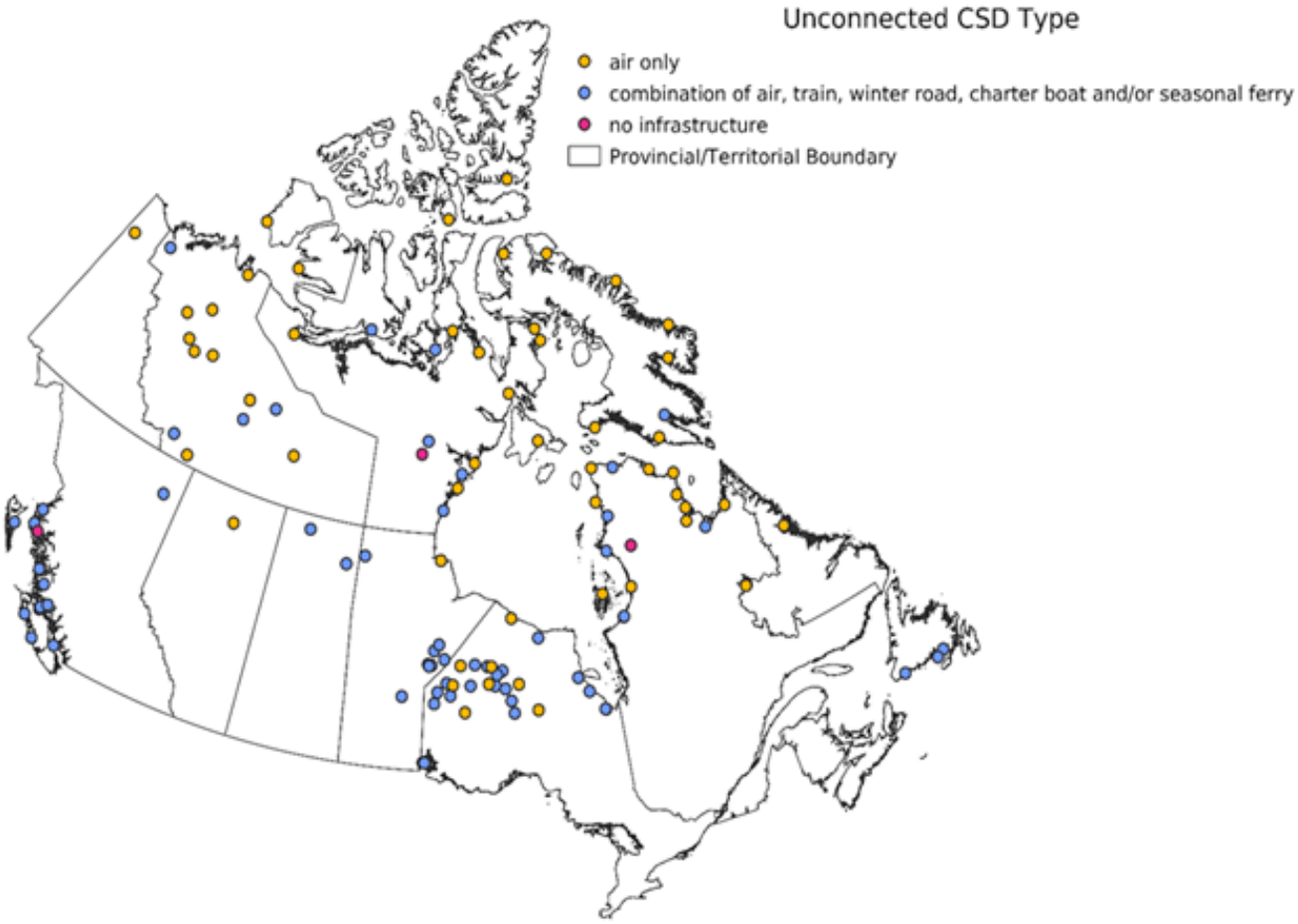
Updating the CSD-PopCtr Travel Cost Matrix

The 2021 Index of Remoteness travel costs were generated using travel network distances between CSDs and PopCtrs multiplied by the CAA operating cost of a vehicle per kilometer. Unlike in previous years, the travel network distances were calculated using the Valhalla[11] open-source routing software on the Open Street Map road and ferry network. Valhalla routing software finds the most direct route, according to the input parameters, on the main road and ferry network between CSD and PopCtr pairs within 300 km of each other. If no population centre is within 300km of the CSD representative point and the CSD is connected to the main road/ferry network then the closest population centre further than 300km is selected to pair with that CSD.

For all CSD-PopCtr pairs that were within 300 km in linear distance, the travel distances obtained from Valhalla were converted to travel costs by multiplying the CAA operating cost of 0.18 dollars per kilometer by the network distance. In short, this translated to a cost of $14.40 per hour travelled assuming a speed of 80 km/h (80 km/h x $0.18/km).

For CSDs with no population, a Index of Remoteness was generated if Valhalla returned travel distance data for that geography and had at least one PopCtr within 300 km in linear distance.[12] If no distance data was returned by Valhalla, the CSD was classified as unconnected For unconnected CSDs with no population, it was assumed that no other transportation infrastructure existed inside its boundaries. No Index of Remoteness was generated for these cases.

Figure 2 Spatial distribution of unconnected census subdivisions of Canada by transportation infrastructure type



Notes: (i) each dot relates to the representative point for a CSD.
Source: Authors' computation.

Compiling the Index of Remoteness

Similar to what is shown in the original paper, the agglomeration level (AL) for CSD i can be described as the summation of the populations of the population centres (Pop) that can be reached by CSD i, divided by a measure of the proximity (travel cost C) of each population centre to CSD i; for all population centres within or equal to a set travel cost (C) of $36.00 to CSD i, which is the cost of traveling 150 minutes (2.5 hours) on the main road/ferry network. In mathematical terms, equation (1) illustrates the formula and conditions that define remoteness level.

$$\mathrm{AL}_i = \sum_{k=1}^{n} \left(\frac{\mathrm{Pop}_k}{C_{i,k}}\right) \text{, where} \qquad (1)$$

a. $Pop_k / C_{i,k} = 0$ for all $C_{i,k} >$ $36.00 *(150 minutes)*; and

b. $C_{i,k} = C_{i,closest}$ if there is no PopCtr with $C_{i,k} <=$ $36.00 (150 minutes) and i is connected to the main road network*;* and

c. $C_{i,k} =$ $3 if $i = k$ or if $C_{i,k} <$ *$3 (12.5 minutes)*.

In equation (2), the results from equation (1) are converted to an index (or *RI*) by taking the natural log of the ALs, rebasing the values, and bounding them between "0" and "1". Also, as in the original paper, for ease of communication the re-based values are subtracted from "1" so as to have the Index of Remoteness equal to zero for the least remote CSD and equal to one or the most remote CSD.

$$\mathrm{RI}_i = 1 - \frac{\mathrm{AL}_i - \mathrm{AL}_{min}}{\mathrm{AL}_{max} - \mathrm{AL}_{min}} \qquad (2)$$

It is important to note that the 2016 update introduced the terms *agglomeration level* (*AL*) for the left-hand side of equation (1), and *Index of Remoteness* (*RI*) for the left-hand side of equation (2).[13] In the original paper, the terms "remoteness index" (or RI) and "Index CSD", respectively, were used. With the 2021 update, such as in 2016, an intertemporal analysis of remoteness was conducted. Intertemporal analyses are more meaningful when conducted on measures that are comparable over time (equation (1): agglomeration level) as opposed to those whose interpretation depend on a given time period (equation (2): Index of Remoteness). Comparing *RI* (i.e., equation (2)) over time can describe the dynamics of remoteness in relative terms but cannot answer questions such as "did *CSDi* become more or less remote in absolute terms over time?"[14] (see Box 1 for an example). Thus the agglomeration level is used for these purposes.

Changes in agglomeration level (AL) VS Changes in remoteness index (RI)

Using the CSD for St. John's as an example, the following illustrates why estimating changes in remoteness over time with the index can yield misleading results depending on what type of analysis is being done.

In accordance with how AL and RI are defined in equations (1) and (2) above, the following interpretations apply: positive changes in AL imply increasing agglomeration (or decreasing remoteness), while positive changes in RI imply increasing remoteness (or decreasing agglomeration).

For St. John's, the 2016 and 2021 results were as follows:

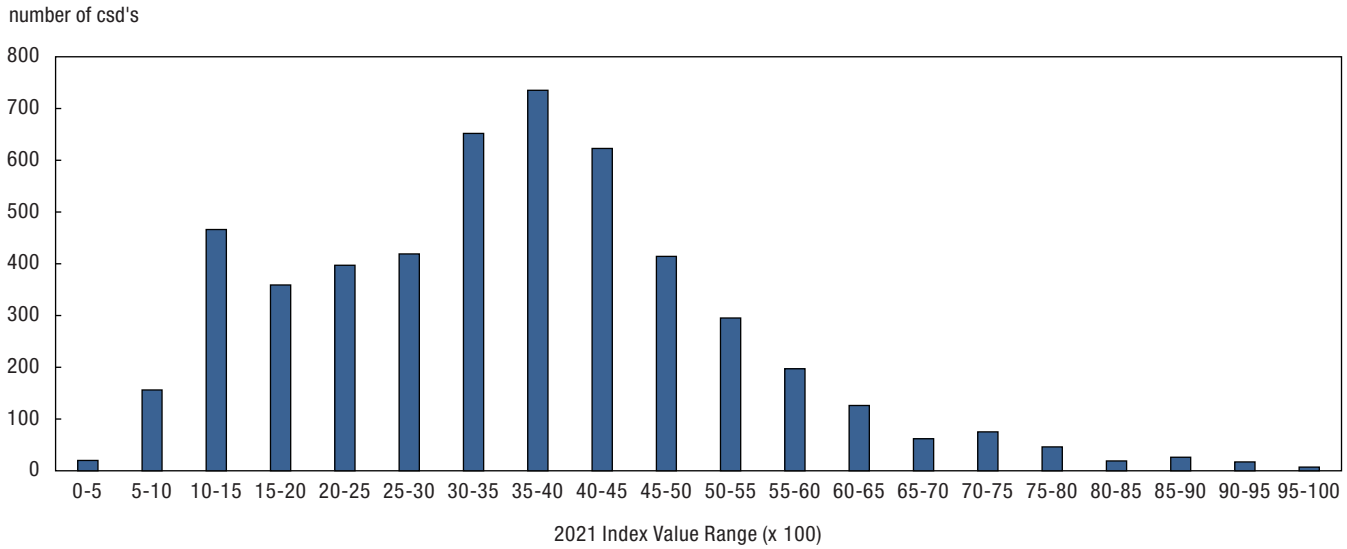
	2016	2021	Percent Change	Interpretation
Agglomeration Level	11.0179	11.0522	+0.31%	The agglomeration level of St. John's increased so St. John's became less remote in absolute terms
Index of Remoteness	0.2430	0.2470	+1.66%	The Index of Remoteness of St. John's increased so St. John's became more remote in relative terms

For many uses of the data, it would be illogical for St. John's to be simultaneously less and more remote. The reason that this result can occur is because of the transformation applied to AL to obtain RI (equation (2)) makes use of the minimum and maximum AL values observed in the given period. Since these minimum and maximum values change over time an "apples-to-apples" assessment is not feasible without running the index together for 2016 and 2021.

2021 Results

Of the total 5,161 CSDs existing in 2021, a Index of Remoteness value was calculated for 5,112 of them.[15] The 2021 Index of Remoteness had a higher mean (0.357 vs. 0.349) and higher median (0.355 vs. 0.339) than the 2016 Index of Remoteness results. The frequency distribution of the 2021 index values is shown in Figure 3 . The 466 CSDs in the 0.10 to 0.15 range with roughly half of all CSDs falling between 0.20 and 0.45 follows a similar pattern to the 2016 Index of Remoteness

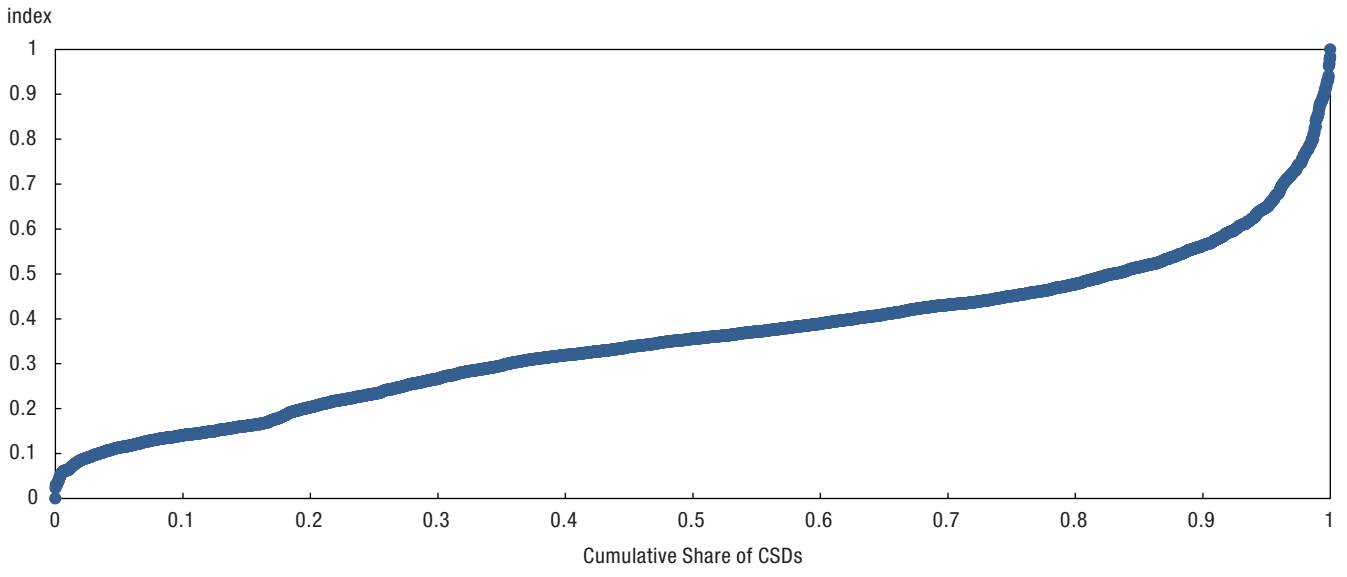
Figure 3
Frequency distribution of the 2021 Index of Remoteness, all census subdivisions of Canada



Source: Authors' computation.

As in 2016, the least remote CSD in 2021 according to the index is Toronto, whose index value is zero. Similarly, as in 2016, the most remote CSD is Grise Fiord with the maximum value of one. Figure 4 shows the distribution of the 2021 index values from smallest to largest (or Toronto to Grise Fiord). The x-axis of the figure shows the cumulative share rank of CSDs. The distribution is somewhat similar to the 2016 version. In 2021 the cumulative distribution rises logarithmically between 0 and approximately 0.2 (on x-axis) and then linearly until 0.75, at which point values rise at an increasing rate with some breaks near the top of the index. Only 190 CSDs, or 3.7%, have a Index of Remoteness value larger than 0.7. In 2016, the equivalent percentage was 4.3%.

Figure 4
Ranked distribution of the 2021 Index of Remoteness, all census subdivisions of Canada

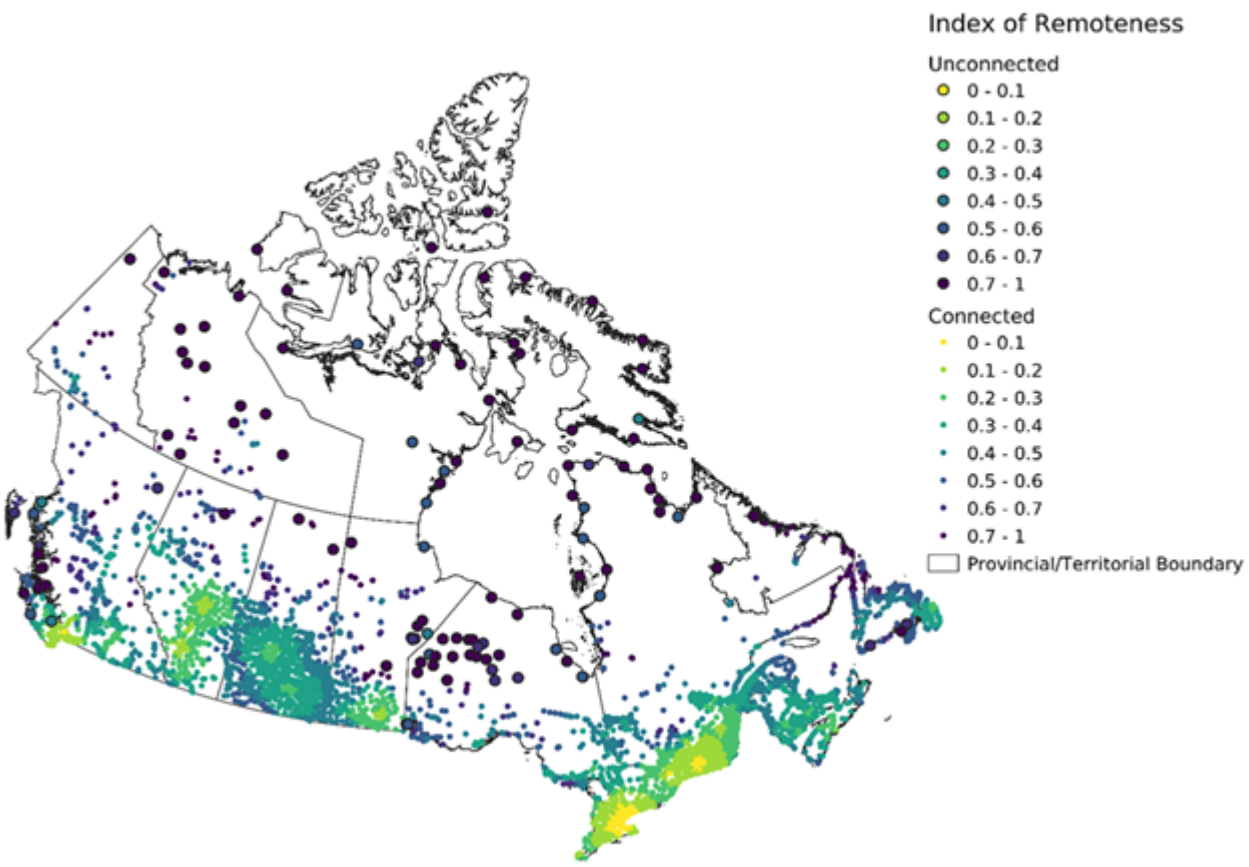


Source: Authors' computation

A colour map for the 2021 Index of Remoteness values is show in Figure 5. As in 2016, CSDs with lower index values (i.e., “less remote”) tend to be in the southern portion Canada along the U.S. border. The CSDs with the higher index values (i.e., “more remote”) are largely located in northern Canada. Again, these results are expected given the location of the largest PopCtrs in Canada.

From Figure 5, it can also be observed that unconnected communities, unsurprisingly, tend to have higher Index of Remoteness values than communities connected to the main road/ferry network. In 2021, excluding CSDs that reported no population, there were 4,710 CSDs connected to the main road/ferry network in 2021; For these CSDs, the average index value was 0.342. The average index value for the 117[16] unconnected communities was 0.774. Users are advised, however, to exercise caution when making comparisons between the connected and unconnected communities. Underlying methodological choices for how to treat communities with no population centres equal to or within 150 minutes travel time (i.e., $36.00 travel cost) or with very different transportation infrastructure can impact the degree of comparability. The benefit of these choices (e.g., choosing the “closest” PopCtr if none existed within the 150-minute travel limit) was that they allowed for the creation of a unified dataset of remoteness that covered all of Canada.

Figure 5
Spatial distribution of the 2021 Index of Remoteness, census subdivisions of Canada



Notes: (i) the above map excludes CSDs unconnected having no population or no infrastructure, (ii) each dot relates to the representative point for a CSD.
Source: Authors’ computation.

Remoteness Over Time

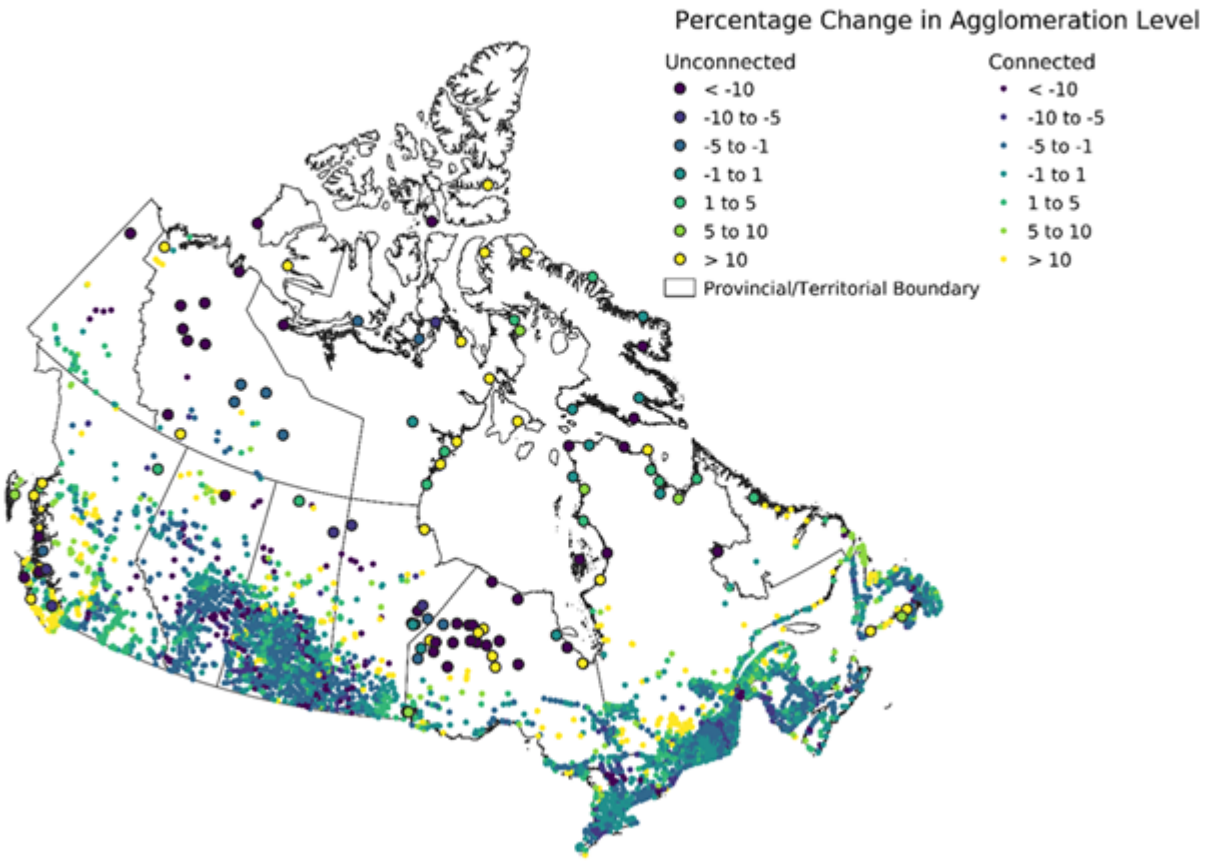
With the 2021 update to the Index of Remoteness series, a temporal analysis of remoteness was done. This section provides major highlights on how remoteness changed between 2016 and 2021. It is important to note that, for the intertemporal analysis, the measure for agglomeration level (AL) will be used. As was mentioned in the earlier section, "Technical Notes", using AL instead of RI allows for a more meaningful comparison of remoteness (or its converse "agglomeration") over time.

For any given CSD, its agglomeration level may change over time for various reasons. Some of the key factors are:

1. The PopCtrs used to calculate travel costs experienced an increase or decrease in population.
2. The number of PopCtrs used to calculate the travel cost matrix increased (i.e., new PopCtrs) or decreased (i.e., disappearing PopCtrs).
3. Transportation costs increased or decreased[17], which includes the case where the connectivity to the main road/ferry network for a CSD changed as well as, for certain unconnected communities, changes in airfares.
4. For the unconnected CSDs who remain unconnected, a further factor arises. For these CSDs, only the cost of transportation to, and population size, of the most accessible PopCtr is used in the calculation of agglomeration. This fact may lead to paradoxical results in that the direction of the change in agglomeration will be determined by the balance between the impacts of population size and travel costs from switching reference PopCtrs (for cases where the two factors act in opposite direction). For example, in general terms, one would expect that the introduction of a new and more accessible PopCtr to an unconnected CSD would result in the agglomeration level for that CSD to rise (thus, remoteness would decrease). In actuality, if the population of this new PopCtr is much smaller than the one that was previously used in the calculation, the agglomeration level of this CSD may in fact decrease (thus, the remoteness would increase).

The percentage change in AL for CSDs that existed in both the 2016 and 2021 Censuses (4,964), and reporting ALs in both periods, is shown in Figure 6 below. The average change in agglomeration level across all CSDs was 1.20% - positive changes signifying a community became less remote. Of the 4,964 communities considered in the temporal analysis, 38.72% (or 1,922) saw their agglomeration level rise more than 1% (i.e., remoteness fell). Another 30.76% (or 1,527) of CSDs experienced a change in agglomeration level between –1% and +1%, and the remaining 30.52% (or 1,515) of CSDs saw their AL drop more than 1%. Of the 588 CSDs (or 11.85%) that experienced changes greater than ± 10%, 238 CSDs (or 4.79%) had a change less than -10%, and 350 CSDs (or 7.05%) had a change greater than 10%. As a term of reference, when comparing changes between 2011 and 2016, the majority of CSDs (53% or 2,537) experienced a change in agglomeration level between -1% and +1%, while only 130 CSDs (or 2.7%) experienced changes greater than ± 10%.

Figure 6
Spatial distribution of the percent change in agglomeration level for all census subdivisions of Canada common between 2016 and 2021

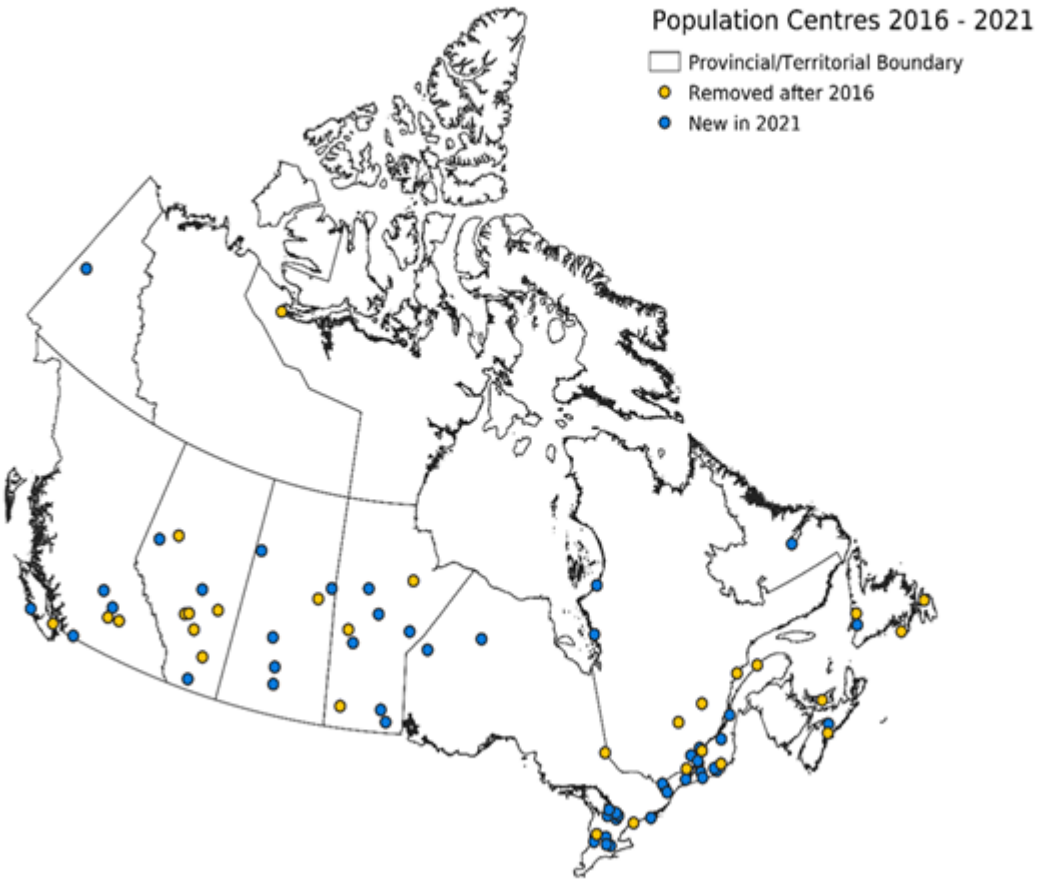


Notes: (i) CSDs unconnected with no population or with no infrastructure were excluded from the map, (ii) a positive change means an increase in agglomeration (i.e., decrease in remoteness).
Source: Authors' computation.

A key factor influencing the change in agglomeration level over time for a given community is the appearance and disappearance of population centres.[18] There was a total of 1,026 PopCtrs in 2021. Of these, 50 were new since 2016. The 2021 Census also saw the removal of 29 PopCtrs from the geographic frame as they no longer satisfied the definitional critieria of a PopCtr.[19] The new and disappearing PopCtrs are shown in Figure 7.

In Figure 6, it can be seen that many CSDs in the southern and central portions of the Prairie Provinces experienced decreases in agglomeration levels in the range of -1% to <-10%. When looking at Figure 7, we see that this region also saw the removal of many PopCtrs. Given the importance of PopCtrs in the calculation of agglomeration, this evolution likely helps explain some of the dynamics that are being observed.

Figure 7
Map of new and disappearing population centres between 2016 and 2021



Source: Authors' computation.

Another finding, which is also observable in Figure 6, is that changes in AL in the northern and more isolated communities appears to be more volatile than what is observed in southern Canada. Of the 588 communities who experienced changes greater than ±10%[20], 69[21] were unconnected to the main road/ferry network in 2021. Of these, 48 had travel costs based on airfare data (either directly or indirectly through the modelling discussed earlier). For these communities, in the absence of major changes in population size or choice of "closest population centre", their more extreme change in agglomeration level may be the result of increases or decreases in the cost of air transportation, a service whose price may vary significantly based on a multitude of factors, including not least of which the time of year. Hence, although the Index of Remoteness value generally captures the comparative conditions of these communities, relative to the rest of Canada, more work could be undertaken to understand how airfares are impacting the resulting estimate of the cost of transportation, and consequently, the calculated agglomeration levels.

This document simply highlights trends and the overall change between the 2016 and 2021 Indices of Remoteness and does not delve into the many potential factors that can impact the Index of Remoteness.

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