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Rural broadband: Gaps, maps and challenges

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ABSTRACT

This paper examines challenges to evidence-based decision-making in the design and implementation of rural broadband investment programs. Our focus is on Canada, and the apparent need for further intra-rural broadband research and better data and mapping for informing public investment decisions, but similar challenges are evident in the international literature. Based on proprietary telecommunication provider datasets, the Canadian Radio-television and Telecommunication Commission (CRTC) estimates that broadband services with advertised speeds that meet its basic universal service targets (50 Mbps download and 10 Mbps upload) are available to 87.4 percent of households in Canada. In rural areas however, services that meet CRTC's speed targets are available to 45.6 percent of households. Moreover, effective speeds and service quality levels that suppliers deliver and users experience tend to fall well below the government's aspirational targets. In response to demand for better broadband, a variety of initiatives are directing public investment to the deployment of regional and rural broadband networks, which are typically owned and operated by private companies. There remains a serious lack of relevant data and its effective use in creating rural broadband strategies and managing public investment projects. Evidence from the literature suggest that this affects the degree and quality of geospatial and econometric analysis that results in a limited empirical basis to allocate scarce public investments, aggregate demand of consumers/communities, and assess the outcomes of rural broadband initiatives ex post. This paper provides a historical overview of rural broadband development in Canada and questions if the body of knowledge to inform public investment initiatives has grown sufficiently to ensure their effectiveness and sustainability. With a regional case from southwestern Ontario, Canada, we discuss the findings of the literature review, characterize the broadband data challenge, and discuss the importance of proprietary provider data cross-referenced with Internet user experience data.

1. Introduction

> "High speed access to the Internet is one bit of infrastructure that shrinks our geographic isolation. It matters more than rail, road, or sewer and water. It is the underpinning for the new economy. Employment in the agriculture industry continues to, and will, continue to shrink. Maintenance of a critical mass of (rural) population is dependent on bridging the digital divide. These are not buzz words if you live on the other side of that divide. The very first dollar going to rural areas should be targeted at high speed, period. We will do the rest."

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National Broadband Task Force (Canada, 2001) survey participant from Saskatchewan, extract from "The New National Dream: Networking the Nation for Broadband Access."[1]

In Canada, around 20 percent of the population resides full-time in census-defined rural areas (Statistics Canada, 2018).[2] Rural areas contribute approximately 23 percent of the national gross domestic product. Over the past two decades, significant public and private investments have helped expand "high-speed"/broadband Internet access to rural areas and remote communities. Yet, access to high quality and affordable broadband continues to be an elusive "national dream." Many rural Canadians no longer make their primary livelihood from farming, or other natural resource-based production. Since the start of the 21st century, Canada's rural areas have experienced substantial employment diversification which requires reliable information and communication technologies (ICTs). Regions with a high age-dependency ratio (relatively older and younger populations) also require online learning and telehealth services, particularly during the current COVID-19 pandemic as people now have little option but to work, study and stay at home (Canadian Rural Revitalization Foundation, 2020). A further driver for rural connectivity is the advent of cloud-based data intensive, precision technologies in agriculture and rural natural resource management that provides food, water and a range of primary goods for domestic use and export (Chowdury and Hambly, 2018).

From a telecommunications perspective, the unique context of most rural areas, in Canada, and around the world, involves physical distance from markets, low population density, and conditions such as weather, topography and geographical remoteness. All these factors present challenges for telecommunications infrastructure development, namely in the context of this paper, broadband Internet access infrastructure. The private sector Telecommunication Service Providers (TSPs) own and operate broadband infrastructure and services in Canada. With notable exceptions of community or municipal-owned networks, the market, subject to regulation by the Canadian Radio-Telecommunications Commission (CRTC), supplies rural Internet connections. Three levels of government (federal, provincial or territorial and municipal) try to incentivize supply with subsidies to serve and upgrade infrastructure in unserved or underserved rural communities, as well as other forms of inducements such as tax credits and concessions (Rajabiun and Middleton, 2013a). Innovation, Science and Economic Development (ISED) is the federal ministry responsible for broadband policy support and programming. At the provincial and territorial levels, various agencies may be involved.[3]

Rural broadband is an especially "hot topic" in Canadian policymaking with intense public scrutiny during the COVID-19 pandemic (SCIST, 2018; CRRF, 2020). According to 2019 data compiled by ISED and CRTC, 63 percent of rural households in Canada lacked Internet access services at speeds that meet CRTC's 50/10 Mbps "basic service" target, compared with three percent of urban homes (CRTC, 2019a, 2019b). The problem is acute in northern and indigenous communities, especially where users have little option but to rely on old, slow, and expensive wireless and satellite-based broadband technologies. In a report tabled by the Office of the Auditor General of Canada on rural and remote connectivity it was stated:

> "We concluded that Innovation, Science and Economic Development Canada and the Canadian Radio-television and Telecommunications Commission, according to their respective roles and responsibilities, monitored the state of connectivity but did not share enough detailed information publicly. We also concluded that Innovation, Science and Economic Development Canada did not develop and implement a national strategy to improve broadband Internet connectivity to a specific service level in rural and remote areas" (Office of the Auditor General of Canada, 2018, section 1.82)

In January 2019, the newly established Minister of Rural Economic Development released *High-Speed Access for All: Canada's Connectivity Strategy*.[4] The Strategy aims to deliver 50/10 Mbps connectivity to 90 percent of Canadians by 2021, 95 percent of the national population by 2026, and the hardest-to-reach Canadians by 2030. Response from rural residents and businesses to the aspirational targets is sober, particularly as more urban residential areas can access gigabit service. A widening "digital divide" in Canada makes rural broadband research and policy development a genuine work-in-progress. Broadband supply and consumer demand are growing rapidly, including next generation satellite technologies that promise to meet demand for reliable low-latency broadband in areas where the costs of deploying fixed fibre/hybrid fibre/wireless networks are prohibitive.[5] The next generation fibre, wireless, and satellite infrastructure that enables much faster connections lies at the heart of what is essentially a new "bio-digital economy" where precision agricultural technologies, cloud services and secure big data transfers are paramount, including those digital technologies essential to environmental disaster management (Shim et al., 2007; Chowdury and Hambly, 2018; Bronson, 2019). More broadly, rural areas require broadband-enabled ICTs to support and sustain ecosystems that provide the basics of human life – namely, clean air, water and food at regional and global scales (OECD, 2018). The recent COVID-19 pandemic has made this even more apparent to the majority of Canadians who live and telecommute from suburban and rural areas outside of city centres. All levels of government in Canada cannot help but recognize the role of broadband services for positive social and economic development.

[1] Final Report of the National Broadband Task Force, 2001, page 50. Available at: http://publications.gc.ca/collections/Collection/C2-574-2001E.pdf

[2] Population distribution data (2016) from Statistics Canada is available here: https://www12.statcan.gc.ca/census-recensement/2016/ref/dict/geo045-eng.cfm

[3] In the Province of Ontario, rural issues are mainly the purview of the Ontario Ministry of Agriculture and Rural Affairs (OMAFRA). Rural broadband has been addressed by OMAFRA, in northern areas by the Ministry of Northern Development and Mines, and more recently, the Ministry of Infrastructure. Over the past decades rural Internet access initiatives have also been led from other ministries such as Economic Development, Education and Health. Currently, the Ministry of Infrastructure coordinates the Province's Broadband and Cellular Action Plan, see: https://www.ontario.ca/page/connecting-ontario-improving-broadband-and-cellular-access

[4] See http://www.ic.gc.ca/eic/site/139.nsf/eng/h_00002.html

[5] See https://www.telesat.com/news-events/government-canada-and-telesat-partner-bridge-canadas-digital-divide-through-low-earth

Questions remain about the role the public sector can play in fostering the emergence of high-quality broadband connections that meet growing demand for reliable, affordable, ultra-high speed/low latency Internet access.

This paper proceeds to review the literature and examine a regional case of expanding broadband services in Ontario, Canada in order to identify and discuss the digital gaps, data and mapping challenges in evidence-based decision-making in rural broadband investment programs. We first discuss the emergence of the term "rural broadband" and highlight a few conceptual approaches to research in this area. Collapsed into characterizations of "last mile", digital divide, or incentivized as special projects, rural broadband features in thousands of pages of Canadian policy and advocacy. The next section provides an overview of our research methods and sources of data for the paper. The findings of the literature review suggest that over time, the academic work appears to shift methodologically, from only small sample, qualitative case studies to quantitative analyses with mixed methods and bigger data sources. There is rare access, for academic research purposes, to proprietary telecommunication data, which limits the scope for outcome analysis, program evaluation, and learning from the mistakes of the past. Improved data stewardship, we argue, is needed to address the challenges associated with reconciling official government speed mapping data and service quality levels users experience. There is limited econometric analysis with time-series/panel data and bigger datasets of user experience/consumer survey data. In the second part of the paper, we discuss the broadband gaps, data and mapping challenges in the context of southwestern Ontario, where a major broadband investment program is underway. We identify analytical considerations involving data and mapping that are relevant to rural broadband investments. In the end, we find there is more effort needed to collect bigger and better data to support more efficient and effective decision making by public policymakers and private sector providers.

2. Defining rural broadband in Canada

Rural broadband is a concept that dates back nearly five decades, well before the advanced digital technologies known today. The term "rural broadband" was initially used in policy documents in the 1970s, but it was a very different era of telecommunications.[6] The first satellite-to-home (Ku band) broadcast in Canada took place in 1978 in Shirley's Bay, 17 km west of the national capital city of Ottawa (playing, what else, a Stanley Cup hockey game). In 1983, the research facilities at this same site had the first permanent connection to the Internet (ARPAnet) in Canada. In 1995, Rogers Communications was first to offer broadband (i.e. as opposed to dial up) home Internet in North America, serving residential premises in and around Newmarket, Ontario, a commuter city in the Greater Toronto Area (Rogers Communications, 2014). Over the next decade, first generation broadband infrastructure was deployed by centering on dense, urban environments with large numbers of subscribers (Wilson, 2000). Broadband Internet was initially available in relatively more densely populated rural communities of Canada through service sites at public premises (e.g. schools, libraries, etc.) (Moll, 2012).

In 2006, it was estimated that approximately two-thirds of rural southern Ontario had no residential access to Internet or only dial-up Internet access (Hambly et al, 2007).[7] A decade later, broadband services were more pervasive but the availability of service with higher speeds generally remains much lower than in urban areas which usually have upgraded DSL, cable, and increasingly fibre-to-the-premises (FTTP) broadband technologies (CRTC, 2019a, 2019b).

In 2016, (CRTC Telecom Regulatory Policy 2016–496), the federal telecommunication regulator recognized that broadband access in Canada has in fact become an essential and "basic service" required for social and economic participation under the *Telecommunications Act*, adopting aspirational speed targets of 50/10 Mbps that "are to be the actual speeds delivered, not merely those advertised."[8] The CRTC also established, for the first time, a process to specify minimum universal quality of service standards in terms of latency and, in 2018, adopted a basic service latency threshold of 50 ms, a jitter threshold of 5 ms and a packet loss threshold of 0.25 percent, measured during peak times (i.e. from 7p.m. to 11p.m. local time on weekdays) (Telecom Decision CRTC 2018–241). While policy commitments to the implementation of this minimum quality of service standard remain on paper, their adoption is particularly important for consumers in rural communities where the business case to invest in capacity enhancements and new low latency technologies tend to be relatively weak (or non-existent). Rural users are familiar with how network resources become increasingly oversubscribed as demand grows, generally making the connections slow and unreliable. In rural areas where additional revenues expected from capacity enhancements and competitive pressure on suppliers are relatively limited, effective bandwidth available to users can diverge significantly from the maximum theoretical "best effort" (up to "X" Mbps) speeds suppliers advertise and/or are specified in retail contracts (Rajabiun, 2018a, Rajabiun, 2018b).

The characterization of rural broadband in Canada as "market failure" is apparent in the documentation from various consultative processes. For example, rural community interest groups have made repeated calls to impose wholesale access obligations on fibre transport facilities that aggregate traffic from dispersed settlements and enable communities in areas where incumbent providers have

[6] The journal, *Telecommunications Policy* (March 1977) made early mention of the term "rural broadband" reviewing the US Congress Office of Technology Assessment (OTA) deliberations and report entitled "The feasibility and value of broadband communications in rural areas".

[7] Initially, data packets and throughput were insignificant, compared to the present day. Download speeds measured in kilobits and dial-up modem connections were the norm (with a top speed of 56 kbps or 500 times slower than a present-day DSL connection of approximately 28 Mbps).

[8] For an analysis of the evolution of universal service policies at the federal level and decision to classify high speed access a "basic service" see Rajabiun, R. (2020). Technological change, civic engagement and policy legitimization: Perspectives from the rise of broadband Internet as an essential utility in Canada. *Government Information Quarterly*, *37*(1), 101403.

limited incentives to invest.[9] Analysts see such options attracting private sector entrants satisfied with a lower rate of return than large incumbents and/or the deployment of cooperative and municipal networks (Rajabiun and Middleton, 2013b; Mcnally et al., 2018; Taylor, 2018). The forbearance policy may be an efficient strategy in urban centres where it is economically profitable for multiple providers to deploy competing networks. This is definitely not the case in remote, rural, or even suburban areas. In these spaces building multiple facilities is either not feasible at all without public subsidies and/or leads to inefficient duplication and "over-investment" in old technologies. This leads to strategies like "sweating the copper" as Rajabiun (2018b, p. 4) states, "In the short term capital expenditures to upgrade legacy platforms may seem justified from an accounting cost minimization perspective in terms of improved headline speeds (i.e. "up to" x Mbps), but in the medium to long term capital expenditures on old technologies will have to be stranded as legacy copper degrades, decommissions and is replaced with fibre."

In the next section, we outline the methods used to explore the policy literature in Canada, and more specifically, Ontario, on rural broadband, noting a rapid set of developments (2017–2020) that make research highly dynamic. The policy literature includes references to the issues of broadband data, measurement and mapping that adversely affect rural broadband investment decision-making. We also explain the methods used for the case of rural broadband in southwestern Ontario – this case is documented in order to allow for a further discussion of how broadband gaps are understood and need to be reconsidered as more data-rich analysis develops.

3. Materials and methods

Analysis of the literature for this paper uses thematic coding of literature in a documents database started in 2006 and maintained by the Regional and Rural Broadband (R2B2) project at the University of Guelph (Canada). Informed by the efforts of Salemink et al. (2017) who review rural broadband literature (mainly focused on Europe), we performed additional searches for word frequency in titles and abstracts of academic journals in four databases: Web of Science (WoS), JSTOR, Google Scholar and ScholarsPortal Journals, grouping the finds thematically. The search dates are 1976 to 2020 (June).[10] We drew from the co-authors' experience working with all three levels of government on economic and geo-spatial aspects of broadband development, including input into CRTC and Cabinet appeal processes. The R2B2 Project team crawled webpages of regional/rural/remote broadband networks or projects in Canada, as well as government, non-governmental, Internet service providers and industry websites. We examine purposively selected webpages from similar research projects or think-tanks in the US and Europe. A total of 1397 references were identified, primarily made up of published academic research papers and policy reports/documentations.[11] Additionally, relevant media/editorial material, websites and notes/testimonials were available (n = 119).

For explanatory purposes, this paper also uses a regional case from rural southwestern Ontario. We analyze and map Internet use and infrastructure data which is collected under a research partnership between R2B2 project and the Southwestern Integrated Fibre Technology Inc. (SWIFT), a broadband initiative established in 2012 by municipalities represented by the Western Ontario Warden's Caucus (WOWC) along with other member communities in Niagara Region and Caledon in Peel Region, located within the Greater Toronto Area (WOWC, 2012). The R2B2 project collaborates with SWIFT to support areas such as data stewardship, geo-spatial and economic outcomes analysis. SWIFT has data provided under non-disclosure agreements (NDA) from TSPs and with the R2B2 project collects data with residential and business surveys as well as public sector use datasets (SWIFT, 2020). The surveys collect quantitative data on the premise's primary Internet connection (i.e. type, bandwidth and costs) and use (reliability, relevance and needs at premise). The surveys embed the Canadian Internet Registration Authority (CIRA) Internet Performance Test (IPT), which runs on the Measurement Lab (M−Lab) Network Diagnostics Tests platform (CIRA, n.d.; R2B2, 2019). For illustrative purposes only, we will use examples from 2019 data.

What lies outside the scope of this paper is an in-depth comparison of literature, approaches to data collection and rural broadband program design in Canada with other countries and incorporating more recent COVID-19 service levels and user experience data. This remains on-going work that will need to recognize there is no consistent global standard for distinguishing rural from urban, measuring rural broadband supply and use, prices, etc., adversely affecting comparative national benchmarking for rural broadband (Koutroumpis, 2018) and assessing broadband for rural restructuring and regional economic outcomes (Reimer and Bollman, 2010). We also acknowledge the importance of further analysis of Internet access in First Nations communities. On average, only 27.7 percent of households in indigenous communities in Canada have Internet access at the 50/10 Mbps basic service target, compared to 37.2 percent in rural Canada more broadly (CRTC, 2019a, 2019b). We discuss the relevance of findings to other regions in Canada or other countries but we want to acknowledge at the outset the major variation across census rural areas in Canada (CRRF, 2015) and the lack of consensus about how broadband infrastructure quality should be measured (Rajabiun and McKelvey, 2019).

[9] See e.g. submissions to Telecom Notice of Consultation CRTC 2019–406, Call for comments regarding potential barriers to the deployment of broadband-capable networks in underserved areas in Canada. https://crtc.gc.ca/eng/archive/2019/2019–406.htm

[10] "Rural" "Canada" "broadband" were the top three included terms with other terms such as "digital" "connect*" discussed in this paper. Exclusions were set for "narrow band" and "broad band" which refer to vegetation and (rural) remote sensing spectral indices and finds of "broadband" from this collection of papers were deleted.

[11] Book chapters are counted as research papers. We acknowledge our subjectivity in distinguishing organizational literature or commissioned studies from consultant reports or research papers.

4. Results of the literature review

We concentrate on the identified findings in the R2B2 documents database for three areas of analysis in this paper. The first area is the dominance in the assembled literature of the argument that a rural digital divide persists into the second millennial decade, even in Canada's relatively more populous provinces such as Ontario (38.8% of the national population) and urbanized regions such as southwestern Ontario. The second theme is that closing the gap requires public investment, how rural broadband is "projectized" and the extent to which this policy approach has made a difference in closing rural digital divides. Third, and finally, we wrote this paper to speak to the telecommunications research and policy communities, and therefore we purposively review the literature concerning broadband data and mapping in Canada. In the following section we will examine these findings in the context of the regional case of southwestern Ontario.

4.1. Terminology shifts but the rural digital divide persists

In Canada, "rural broadband" has progressively displaced the term "rural telecommunications" within contemporary policy and academic literature. The review of documentation indicates that the topic has long been associated with discussions of unequal socio-economic development in Canada (Paisley and Richardson, 1998; Ramirez and Richardson, 2005; Reimer et al., 2019; Greenwood, 2010). The term "last mile" cross-references with rural broadband in engineering/technical and social science literature. From the perspective of large telecommunications companies, broadband infrastructure is built out from "first mile" connections to access network (middle mile or distribution network which can be multipoint) then on to access network (last mile, usually multipoint) and then to the customer or user network. While first/middle/last miles of connectivity are more likely to be descriptors for broadband transport, the academic literature appropriates this term to discuss universality and equality of access (McMahon et al., 2014; Strover, 2003). The landmark initiative known as the First Mile Connectivity Consortium (FMCC) is an example of inclusive connectivity.[12] From its establishment in 2004, FMCC has facilitated an outstanding body of knowledge and advocacy for remote and northern rural broadband.

From 2010 onwards, we find that "rural broadband" co-associates with terms such as *smart communities*, *intelligent regions* and for example, *beyond the smart city*, *the connected farm* and *smart farming* (ICF Canada, 2011; Bronson, 2018; CENGN, 2018). Other terms such as *digital* and *connectivity* co-associate with rural broadband, especially in the policy and program documentation. The investment program titles of note are, "Rural Connections" (two phases between 2007 and 2012), "Digital Canada 150" (two phases starting in 2014) and "Connecting Canadians" (2014–2018), which was rolled into "Connect to Innovate" (2019–2021).[13] As well, CRTC Telecom Regulatory Policy 2016–496 created a new $750 million over five year Broadband Fund aimed at supporting fixed and mobile wireless broadband development in rural areas and remote communities with very poor connectivity. Currently, the $1.75 billion Universal Broadband Fund (UBF) receives applications as part of the federal government's current plan "High-Speed Access for All: Canada's Connectivity Strategy" (Government of Canada, 2019).

Shifts in terminology point to the persistence of the asymmetrical hierarchy of urban to rural connectivity gaps in Canada. In the 2000s for example, the Community Informatics research group in Canada was particularly active offering conceptual frameworks, action research and in-depth qualitative case studies (Clement et al, 2012). The oft-cited *digital divide,* remains a term entrenched in the Canadian policy literature, and to a lesser extent, in the academy.[14] The so-called divide designates sides of information or (digital) development "haves and have nots" that parallel technological determinism arguments in classic divide and dependency theories of communication, media and socio-economic development studies (McLuhan, 1962; So, 1990).[15] There is some comparative analysis of Canada/US digital divides, but the conjecture by authors such as Howard et al. (2010) that broadband gaps across North America were closing have proven to be incorrect (Kozak, 2010). The data to support in depth analysis of dynamic inter-regional and intra-regional digital divides in Canada have received little attention (Carson, 2014).

We find that changes in terminology in Canadian policy and academic literature are consistent with other nations, as observed by Kwon and Kwon (2017) in their bibliometric analysis of the journal, *Telecommunications Policy*. Also, consistent with Gunkel (2003), the term "rural digital divide" in Canada is used far too casually in industry, government and academy as it is around the world. There is not one digital divide in a nation, region, community or household, but rather, "a constellation of different and intersecting social, economic and technological differences, all of which are properly named "digital divide" (Gunkel, 2003:504). As Townsend et al (2013) argue in their research focusing on the U.K., rural communities need broadband investments as much, if not more than their urban counterparts. As we consider below, in the case of southwestern Ontario, rural digital divides can be data-defined, created and remade with data and mapping. Furthermore, rural broadband investment may be best delivered as regional strategies and programs that enable scaling, cross-subsidies, and value creation across various sectors that would ultimately benefit from better broadband.

[12] See the extensive listing of FMCC policy contributions and publications at: http://firstmile.ca/

[13] In the federal Budget 2019, 'Connect to Innovate" was increased to $1.7 billion with $5–6 billion of investment over 10 years (Government of Canada, 2019). Telecom Regulatory Policy 2018–377 committed $750 million to the Broadband Fund See CTI allocation maps at: https://www.ic.gc.ca/app/sitt/bbmap/hm.html?lang=eng

[14] 20 percent of database references examined for this paper contain this term.

[15] Here we note the related concepts used in social and economic analyses such as "rural penalty" (Malecki, 2003) and from McLuhan (1962) the "global village", "death by distance" (Cairncross, 1997) as explored by, for example, by Forman, Goldfarb & Greenstein (2005).

4.2. Rural broadband as a Pilot/Special project

The review locates a body of literature that deals entirely with rural broadband in Canada as a project, often a one-time public investment in fixed network assets to help expand coverage and increase speeds of private sector network providers. For scholars from the field of rural development studies, this is not a surprise because the "projectification" of rural development is well recognized (Douglas, 2010). Rural projects will use demonstrations or pilot initiatives, but also "urban catch up" (equalization) efforts. Two broad types of rural broadband projects are referenced in the literature. There are "greenfield" infrastructure projects, often involving public–private partnership aimed at deploying transport facilities and first generation broadband. Then, there are "brownfield" projects aimed at upgrading or moving to second generation, more scalable, broadband technologies (i.e. fibre-to-the-premises (FTTP) and/or hybrid fibre/advanced wireless). Rural areas are generally characterized as disproportionately suffering from lack of faster packet throughput, dedicated monitoring and secure application systems utilization to support online transaction services applications (Albert and Lebrasseur, 2007). Effectively not engineered in the same way as urban broadband networks, there is limited in-depth study of evolving broadband architectures in Canada such as 5G and their implications for regions and rural areas (Rajabiun and Hambly, 2018a). Only recently, has the Province of Ontario linked cellular and broadband in its action plan (Government of Ontario, 2020).

Scalability of projects and regional networks, defined as scaling to meet future demand growth and technology specifications, is not examined in depth in the Canadian literature. The documentation available is limited only to assurances on project web pages that scalability of technology has been taken into account. Scaling also implicates connectivity across sectors. With few exceptions recent literature positions broadband for niche innovations in precision agriculture (Chowdury and Hambly, 2018; Bronson, 2019) but there is little published work on innovation in which, for example e-Health for humans and animals are linked or infrastructure build outs for energy production includes improved service provision for rural residential telecommunications. In fact, the review of literature suggests that very few broadband infrastructure projects and funding programs in Canada have conducted and/or published evaluation reports (Pant and Hambly, 2016). As part of final audits and closure processes, evaluation reports and data are confidential, and not necessarily archived for ex post impact assessment and program evaluation. Consulting evaluators such as Annis, McNiven and Curri (2005) recognized the difficulty of insufficient data for outcome assessment. For research purposes, evaluation reports may need to be obtained under somewhat complicated official access to information requests, in which, in our experience, redaction is likely. Dinterman and Renkow (2017) assess the impact on the 2002–2007 USDA Broadband Loan Program. In Canada, past initiatives such as Rural Connections (2007–2012) did not release data or facilitate analysis of ex post/impact assessment, but to the extent possible, some general analysis was delivered by academic researchers (Rajabiun and Middleton, 2013b).

In Canada, we do not yet have impact studies comparable to Canzian et al. (2019) on firm performance for upgraded regional infrastructure projects, or studies involving longitudinal datasets for major projects such as the analysis of Chattanooga, Tennessee's offer of gigabit service to urban and rural households conducted by Lobo (2011) and Lobo et al. (2019). One project evaluation (i.e. the case of the Eastern Ontario Regional Network) referenced a preliminary analysis of the network's outcomes on employment and wage growth (Ivus and Boland, 2015). Similar to Kolko (2012), Ivus and Boland (2015) used topography (terrain steepness), finding small positive wage growth in rural areas associated with improved connectivity. "Projectized" public investment for improved cellular and broadband services suffer because local municipalities lack data and metrics for their planning. The wider literature confirms that Canadians experience the type of project assessment challenges recognized by US scholars (Grubesic and Mack, 2016; Mack et al., 2019; Bullen and Ritzo, 2019; R2B2, 2019). The data challenge will be further discussed in the next section.

Finally, in Canada, broadband projects generally arise from a competitive grants mechanism which carries the risk of pitting underserved communities against each other to compete for scarce funds from higher levels of government and leads to the creation of inequities between rural communities. Comparative analysis of intra-regional projects is missing in the literature. Also, as stated in the May 2019, *High-Speed Access for All: Canada's Connectivity Strategy,*

> "Many rural municipalities have very limited administrative resources. Some 60% of rural municipalities have fewer than five administrators, and many have only one. We must make sure that application processes are as simple and efficient as possible so that programs are accessible. We also need to support municipalities as eligible applicants for funding to develop broadband infrastructure, while recognizing that some municipalities have the fiscal capacity to step in as go-to service providers."

The additional administrative burden of complex broadband projects on municipalities appears infrequently in the literature. What is still minimally documented in Canada is the extent to which past projects were affected by a lack of Service Level Agreements (SLAs) which set minimum performance warranties and ex post monitoring of subsidy recipients (Rajabiun and Middleton, 2013b). Promotional webpage content far outweighs research articles or publicly released analysis of large regional projects (e.g. EORN's Broadband Phase 1, 2012–2015, AxiaFibreNet/Alberta Supernet). Gains in coverage and headline speeds in targeted communities are flagged, but as demand for faster and reliable broadband grows over time improvements in quality of service people experience prove to be ephemeral. What fails to be addressed is the difficulty of "one-off" projects/programs to keep up with growing demand for network resources by users that access to improved connectivity enables. With the strong positive demand shock caused by COVID-19 and ensuing quality of service degradation in rural areas, there is growing concern about the lack of sustained support for rigorous research and evaluation of federal and provincial broadband infrastructure programs, argues CRRF (2020).

4.3. Data-informed rural broadband investments

Broadband has become a critical infrastructure for rural economic growth and regional development (Grubesic and Mack, 2016). In

Canada, connectivity expands and promotes local business in rural and northern areas in ways that are not possible without broadband (Cameron et al., 2005; Ashton and Girard, 2013). There are, however, a handful of peer-reviewed papers on the economic outcomes of broadband in Canada, and fewer rural-focused studies. It has long been stated in the US literature (Gillett et al., 2006; Crandall and Lehr, 2007) that broadband plays a crucial role in productivity growth. Broadband creates productivity gains for rural advanced manufacturing companies (Oh and Mardis, 2019) and regionally beneficial rural employment (Pociask, 2004; Lobo et al., 2019). Examining cases in Canada, Ivus and Boland (2015) acknowledge that their analysis of the outcomes of Eastern Ontario Regional Network was constricted by limitations within the available datasets. With attention to the Alberta SuperNet's content and service offerings, Thomas and Finn (2018) examined urban/rural household use of online services (2005–2014) finding that broadband increased Internet access, but not necessarily benefits of access to and use of meaningful e-services and content. Perceived value was affected by cost of Alberta SuperNet broadband Internet. Regional economic studies (e.g. telecommuting in southwestern Ontario in the case of Hambly and Lee, 2018) call for access to more detailed, panel data. The voluntary 2018 Canadian Internet Use Survey re-released in September 2020, has the intent "to increase international comparability, answer government policy-relevant questions, and measure a wider range of online activities, given the rapid pace at which the Internet has evolved."[16] A key broadband challenge in Canada (and other countries) is clearly one of data access, research capacity and methods (Helderop et al., 2019).

Most of the academic literature, specifically, two-thirds of coded references reviewed for this paper, present descriptive case studies of rural broadband in Canada, and of this literature, more than half of these papers focus on technology adoption and specific/narrow applications of telemedicine, education, telework/telecommuting, youth retention and agriculture. The strongest gaps in the literature are methodological and interdisciplinary. The majority of case studies do not include longitudinal data analysis, or employ mixed methods outside small sample surveys. There has also been little interdisciplinary socio-economic analysis that accounts for diversity of Internet needs among rural residents and businesses. Recent analysis has identified the need for connectivity among large and growing numbers of rural home-based businesses, even prior to COVID-19 (Hambly and Lee, 2018). Issues in rural areas such as high age-dependency ratios and affordability of Internet access that are relevant to intra-rural digital divides (Hambly et al, 2007) are beginning to feature more in recent regional broadband planning initiatives (e.g. Durham Region, 2020).

Identification, data collection and use of indicators to offer a realistic picture of the "availability" of access to high speed connectivity represents a critical missing input into Canada-focused rural broadband research over the past decades. The lack of data and measurement adversely impacts the development of effective public policies and private sector strategies required to strengthen the quality of broadband infrastructure in rural communities (both Type I and II errors; i.e. investing in projects where it is inefficient to do so and investing in ones that are not; e.g. overbuilding existing networks due to omissions in data collection). As Rajabiun and Middleton (2013b) indicate, broadband speed, quality and affordability present pronounced differences in Canada. Quality of service can be a pervasive problem in many urban communities of a region in which rural areas (particularly those that are not remote rural) exist. The policy literature generated in the CRTC and Cabinet processes (2017–2019) called attention to the limitations of the traditional approach used by federal and provincial agencies to map and measure "availability" (aggregating granular service data into 25 km sq. hexagons), once featured in the National Broadband Internet Service Availability Map.[17] In particular, submissions from communities from across Canada to government consultations challenged CRTC/ISED's hexagonal approach to broadband mapping based on service offer availability data of Internet service providers and documented that serious concerns about the federal government's approach exist in all regions of the country.[18]

Possibly responding to concerns from the 2018 Auditor-General report criticizing previous federal rural broadband subsidy programs, more commissioned reports with data useful for comparative analysis have become publicly available over the past few years. For example, ISED has made its commissioned annual telecommunications pricing studies available. Pricing (in different service basket levels) of wireline, wireless and Internet services commissioned by ISED are now available, but a number of key relevant data points are only presented at a highly aggregated manner. For example, fibre-to-the-premises (FTTP) rates below the national level or the location of available transport facilities are not published, nor are comparable "availability", pricing, effective speeds/quality of service metrics, at local and regional levels.

Construction of more realistic availability, quality and affordability metrics by federal agencies can provide significant leverage to municipal and provincial governments trying to convince private sector providers to invest in broadband networks communities demand. As Eastern Ontario Wardens' Caucus (EOWC)/Eastern Ontario Regional Network (EORN) stated:

> "Measuring the criteria for eligibility has often, in past programs, been limited to a provider self reporting on their coverage and speeds available. Our experience over the past seven years enforcing contracts with SLAs has demonstrated that the coverage and capacity projections from ISPs are overly optimistic - especially in the fringe of coverage areas, or in geographically challenged areas, and especially when dealing with large scale projects. Any application process must allow the applicant the ability to prove that presupposed covered areas are not actually covered." (EOWC/EORN, 2017. p. 13–14)

In addition to challenges in developing an empirical basis for mapping broadband service availability and quality of service in a fine-grained manner, the review of documentation to date confirms that the database of rural broadband projects/programs in Canada,

[16] See: http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=4432

[17] See: https://www150.statcan.gc.ca/n1/en/catalogue/56M0003X

[18] See Interventions in Application to review and vary Telecom Regulatory Policy CRTC 2018–377 (Development of the Commission's Broadband Fund (CRTC Public Process Number: 8662-S183-201811167) https://services.crtc.gc.ca/pub/ListeInterventionList/Default-Defaut.aspx?en=2018–1116-7&dt=i&lang=e&S=C&PA=t&PT=pt1&PST=a

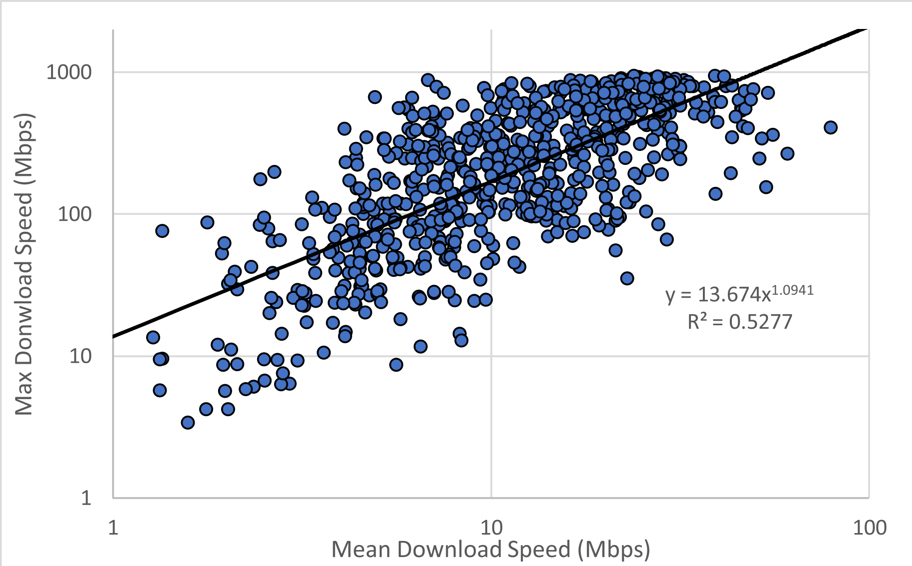

Fig. 1. Measured maximum and mean download speeds in Ontario communities (2019) (log scale; in Mbps; n = 740 communities; ~18 million individual tests; Source: M−Lab NDT/CIRA/R2B2)).

or provincially can be further improved. Developing a dynamic knowledge base that enables comparisons within Canada from past, existing and future broadband investment projects can be valuable for enabling improvements in the design and delivery of rural broadband infrastructure initiatives. Ideally there would be better and more data, including best practice support information for economic and geo-spatial analysis at the community level. These ideas were discussed among broadband researchers and practitioners in R2B2 Project (2019), and collaborative industry partnerships in research are needed.

5. A regional case

5.1. Regional and rural broadband in southwestern Ontario

We now examine the issues identified in the review of literature and policy documents in the context of a major regional broadband infrastructure improvement initiative in southwestern Ontario. The focus of the project is an area bordering the Great Lakes, west of the Greater Toronto Area. The region has approximately 10 percent of the Canadian population, or about 3.5 million residents. A major investment in rural broadband, referred to as SWIFT, Southwestern Integrated Fibre Technology Inc., was confirmed for funding in 2016, and entered its build out phase in 2019. SWIFT is a non-profit municipally-led broadband expansion project led by the Western Ontario Wardens Caucus (SWIFT, 2020).

SWIFT's mandate is to improve Internet connectivity in underserved communities and rural areas across southwestern Ontario. It seeks to leverage public and private funding to deploy new broadband infrastructure to deliver Internet speeds of 50/10 Mbps or higher. The basic financial structure of SWIFT is to subsidize private sector broadband deployment leveraging government funds against industry capital investment. Federal (Canada), provincial (Ontario) and municipal governments (regions and upper and lower-tier municipalities across southwestern Ontario, Niagara Region and Town of Caledon) are all contributors to SWIFT's initial investment phase of nearly 3100 fibre kilometers, approximately 50,000 premises passed and CAD$209 million budget. There are many experiences of understanding broadband gaps, data and mapping challenges in the SWIFT context. Below, we focus on two particular barriers to evidence-based decision-making in rural broadband investment programs of possible relevance for other jurisdictions where policymakers are trying to validate concerns by individuals and businesses about the quality of broadband Internet access, map the state of the network in their communities, and develop strategies for addressing gaps in connectivity.

5.2. User experience

Internet speeds vary across the southwestern Ontario region and there is discussion of the data in other publications (Rajabiun and Hambly, 2018b; Hambly and Lee, 2018). Fig. 1 provides a current (2019) high-level overview of average and maximum measured download speeds across upper and lower tier municipal entities and First Nations communities in Ontario. In 2017, Rajabiun and Hambly (2018b) reported that maximum connection speeds detected in the majority of southwestern Ontario communities tend to exceed CRTC's basic service aspirational speed targets (50/10 Mbps). Average effective Internet connection speeds in most communities, however, tended to fall well below these targets in both rural and urban parts of the region. Fig. 1 plots download speed test results from 740 communities in Ontario representing approximately 18 million speed tests during 2019. The vast majority of plotted

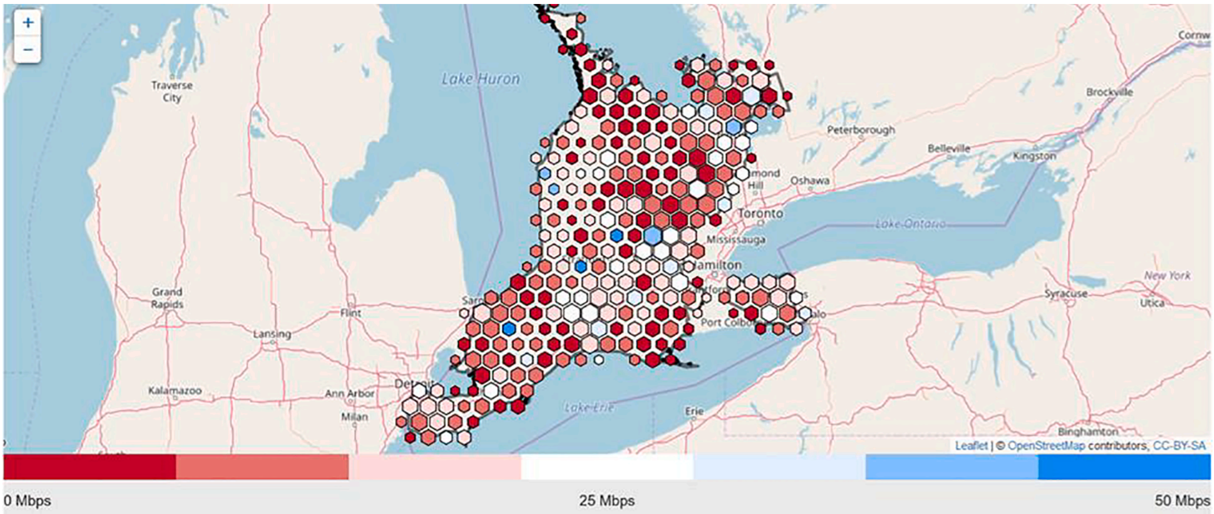

Fig. 2. Average measured download speed in southwestern Ontario. Source: M−Lab NDT/CIRA/R2B2: n = 60,200.

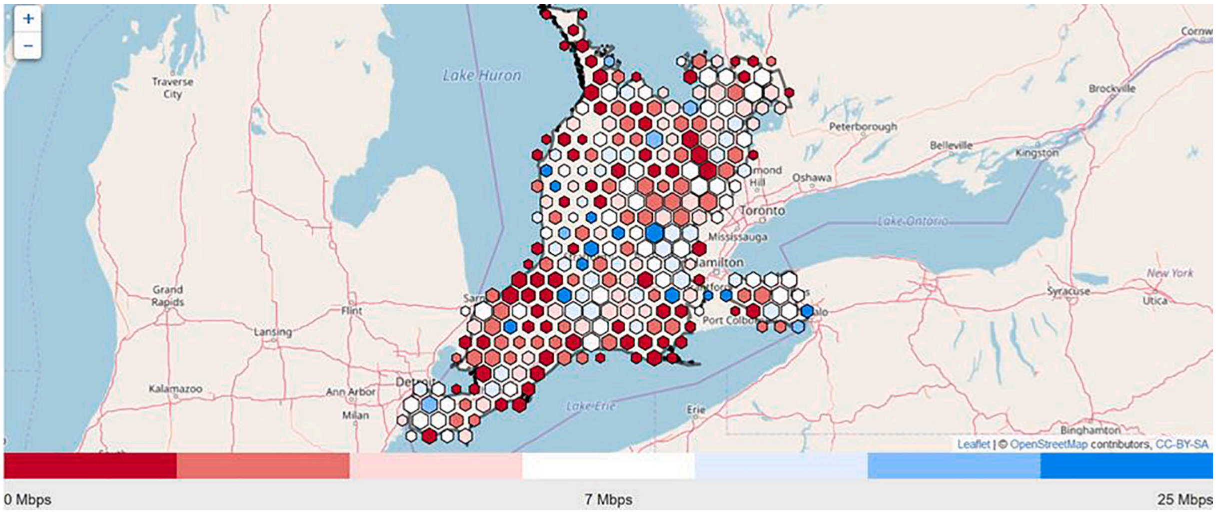

Fig. 3. Average measured upload speed in Southwestern Ontario. Source: CIRA/M−Lab NDT/CIRA/R2B2: n = 60,200.

rural communities in Ontario fall below 100 Mbps (maximum download speeds) and the median and average effective Internet connection speeds in rural communities fall below 50/10 Mbps.

Looking regionally, Figs. 2 and 3 provide the geographic distribution of effective average download and upload speeds as measured by user-initiated tests from southwestern Ontario to third party servers on the "edge of the cloud" in a nearby city.[19] This type of standardized Internet measurement that captures effective service quality levels Internet providers deliver to their customers in particular areas is useful for benchmarking and prioritizing scarce public funds in terms of service quality level people/broadband consumers experience vs. those suppliers advertise (i.e. "up to" xMbps). In addition to enabling validation of concerns about broadband infrastructure quality at the local level and prioritizing scarce public resources in communities that are falling behind further, large-scale user generated data on effective speeds are valuable for baselining and ex post monitoring of SLAs and program/project effectiveness in translating public subsidies into improvements in Internet access quality levels people experience. To better understand the impact of Internet service quality on user behavior and outcomes, R2B2 and SWIFT have integrated connection tests with regional surveys of residents and businesses.

[19] In this case CIRA test servers in Toronto running the standard-based M−Lab NDT test.

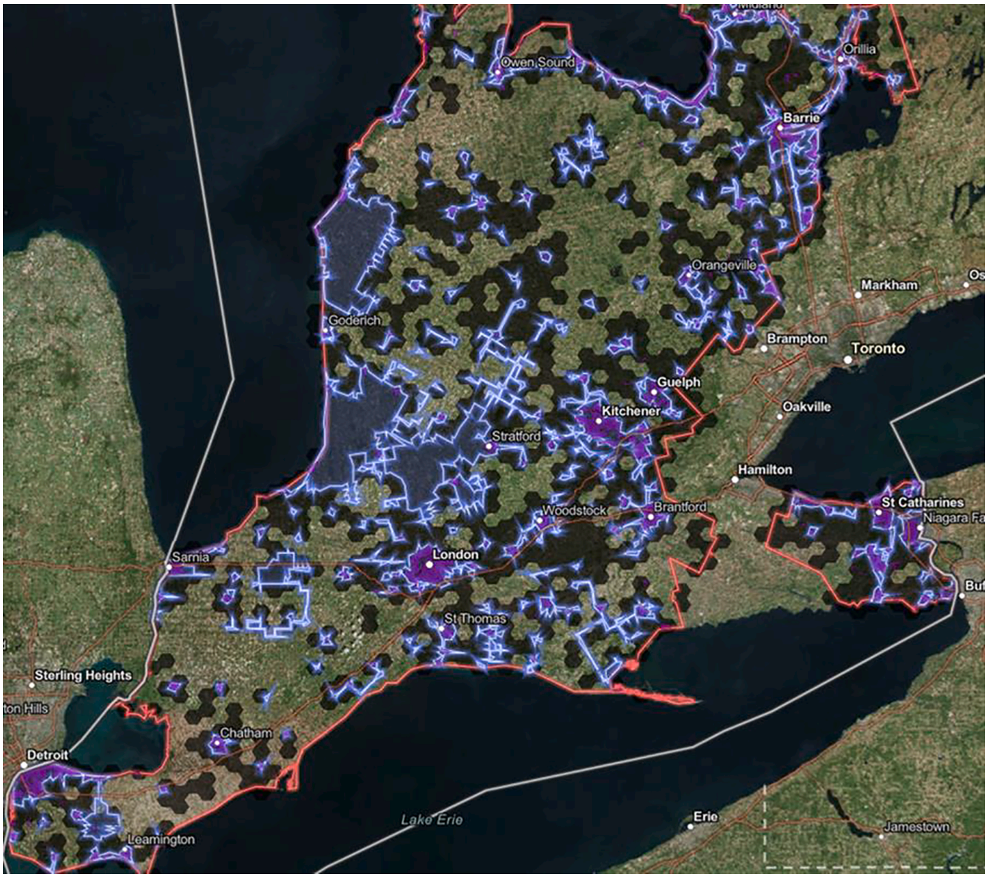

Fig. 4. Availability of broadband services in southwestern Ontario (2019). (Source: SWIFT). (Bright/translucent lines: For analytical purposes we examine 2019 data on the extent of areas where an Internet service provider offers service packages with speeds that met or exceeded CRTC's 50 Mbps download/10 Mbps upload "basic service" target; Purple: Population clusters; Dark hexagons: Areas considered served/ineligible to apply to CRTC fund.) (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article. Please note that current underserved/served areas in the SWIFT program may be updated and appear differently. See: www.swiftruralbroadband.ca)

5.3. Basic service availability

Working with data from Internet service providers in the region, areas that are considered "underserved" based on the 50/10 Mbps "basic service" standard established by the CRTC were identified. Based on assumed parameters, approximately 20 percent of the total households/premises in the region were underserved (as of 2019), which is approximately equivalent to 230,000 premises (Fig. 4).

Using the identified underserved areas and the average industry standard price of installing fibre (including the price of the fibre itself), the total cost of achieving 100 percent broadband penetration in the region is computed. The data sources used to estimate the underserved came from several sources, including proprietary data from telecommunications service providers (i.e. as pre-qualification and Request for Proposal phases of SWIFT) as well as datasets available or subscribed to by the SWIFT project. Mapping various datasets visualizes opportunities for efficient and effective use of public funds.

As discussed above, the traditional hexagonal mapping approach in Canada of served/underserved areas that relied on provider data alone has been problematic. In April 2019, the CRTC and the Cabinet rejected SWIFT's appeal to reconsider the use of hexagonal mapping and consider "partially served" hexagons in rural areas as "served", and therefore ineligible for broadband funding (CRTC, 2019a, 2019b, item 4).

> "Specifically, the Commission determined that to be eligible for funding for a fixed broadband Internet access service project, an applicant must propose to build or upgrade infrastructure in an eligible geographic area, defined as a 25 km^2 hexagon where there is at least one household, as per Statistics Canada's latest census data, but where no household has access to broadband Internet access service at universal service objective-level download and upload speeds (i.e. 50/10 Mbps)."

The Commission therefore considers a hexagon is deemed to be served if there is one household at the "basic service" 50/10 Mbps level because its position is that it is likely that market forces will bring improved levels of broadband Internet access service to the remaining households in the hexagon (CRTC, 2019a, 2019b). The notion that it is "likely" that market forces will help fill in the remaining gaps represents a conjecture, based on little empirical evidence or economic analysis of the local conditions that limit

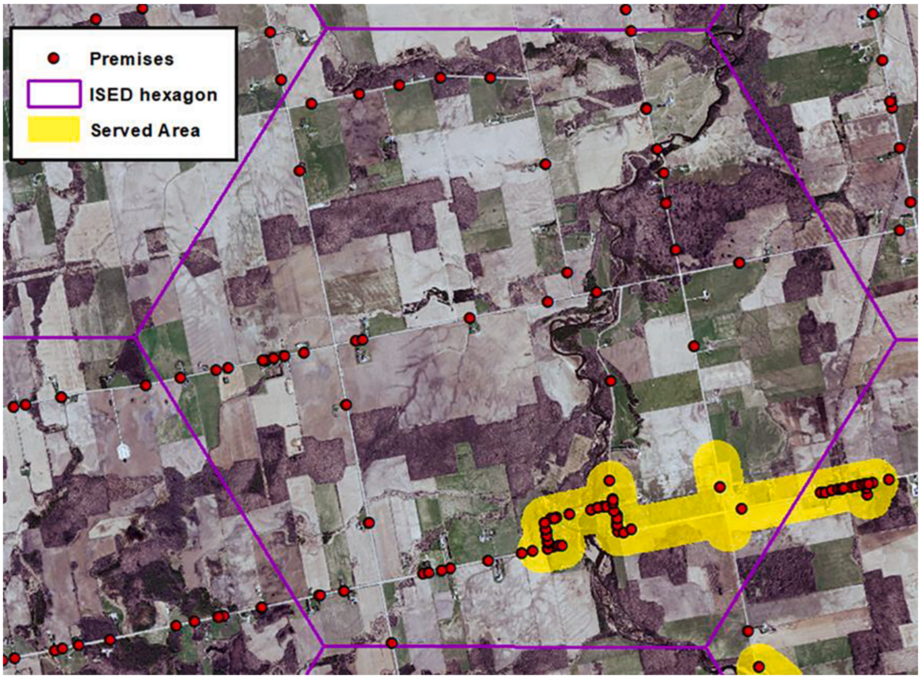

Fig. 5. Overlay of ISED hexagon with premises and "served" areas (Source: SWIFT).

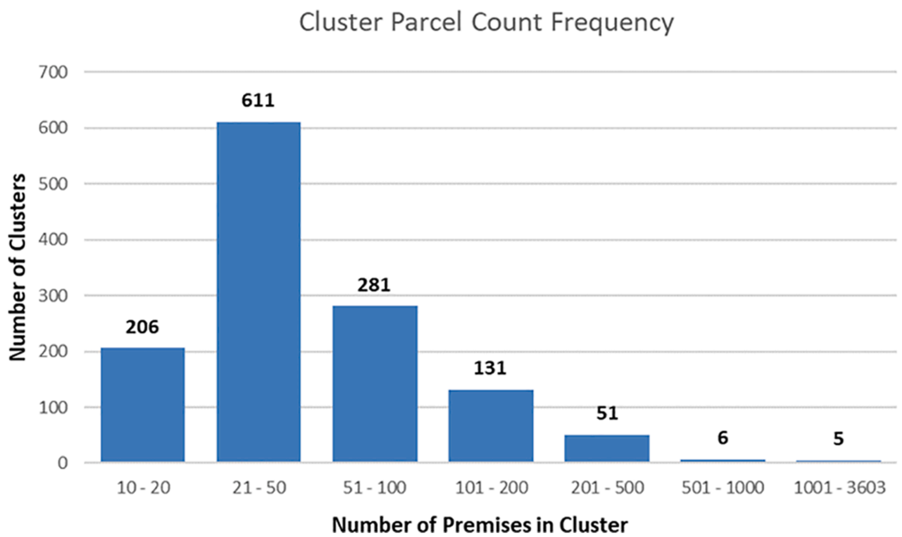

Fig. 6. Size of underserved settlement clusters in southwestern Ontario (2019) (Source: SWIFT).

private sector incentives to invest and close the gaps in that area in the first place. Therefore, in order to evaluate the implications of the traditional hexagonal mapping (which translates to funding eligibility), user location and service provider data were overlaid with the ISED hexagonal framework and CRTC's eligibility maps. The analysis reported here, and in the CRTC appeals process by SWIFT, suggests under the traditional proposed approach, "areas" containing about 100,000 out of the 230,000 residential/business premises lacking access to services with maximum advertised link speeds of 50/10 Mbps would not even be eligible to apply to the CRTC broadband funding mechanism (i.e. erroneously identified as "served" under the federal government's hexagonal methodology).[20] In 2020, central government eventually realized it was time to set aside the traditional approach.

To explain, the key analytical assumption in the traditional hexagonal approach to defining served rural areas is apparently the

[20] To clarify, SWIFT submitted the 2018 CRTC appeal but there were approximately 500 interventions in support of SWIFT's appeal.

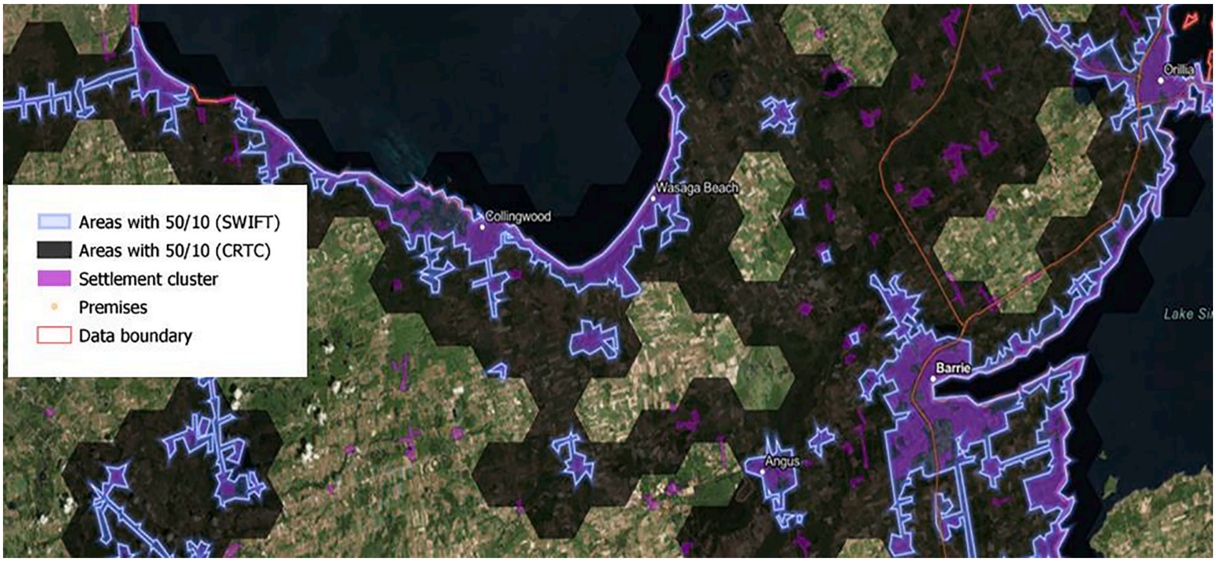

Fig. 7. Availability of basic service broadband: Selected areas in or near Grey County in southwestern Ontario (Source: SWIFT).

notion of an "area." Underserved areas exist because telecommunications service providers typically serve premises in a contiguous manner. The extent of the served contiguous premises that can be converted and conceptualized as an "area" is not clear. The remaining underserved "areas" are not really "areas", but discrete points in space (that is, human populated premises, or premises passed). Grouping the underserved premises into areas forces the analysis to mix underserved and served premises into a single spatial entity - a partially served hexagon, which then defaults to served. This exercise is arbitrary, as well as unnecessary as it is easily feasible to identify the served areas and then let any combination of underserved premises be eligible for funding.

For instance, Fig. 5 provides a low-level illustration of one partially serviced hexagon in southwestern Ontario based on 2019 SWIFT locational and service provider data. The picture documents the general pattern that premises already having access to services meeting the 50/10 Mbps basic service standard (in yellow) tend to be highly clustered in certain part of these partially served hexagons. People at premises without access tend to be scattered in other parts of the hexagon, typically near underserved users in neighbouring hexagons (which may be fully unserved and therefore eligible under the CRTC approach, or partially underserved and therefore ineligible for funding under the traditional hexagonal approach to aggregating service offer data).

If providers have not done so already because of high cost/low expected rate of return in investing in higher quality services outside of the more populous clusters, there is little reason to suspect the weak business case facing them will change in the future. In practical terms, extending services that meet the 50/10 Mbps targets beyond these clusters is typically not economical for telecommunications service providers, unless they can cover another settlement cluster and then cross-subsidize the cost of serving rural homes and business along the way with revenues from the higher density cluster at the end point of the new build. This approach to identifying eligible areas, and exclusion of partially served hexagons, limits the scope for projects covering two or more rural settlement clusters and people along the way across multiple hexagonal areas by supporting infrastructure provider incentives to make these "hops" with high-capacity fibre networks deeper into rural areas and remote communities.

In addition to large numbers of premises outside of clusters with 50/10 Mbps access in partially served hexagons, there are also some larger clusters of users/settlements where market forces have proven insufficient to deliver this basic service target. Fig. 6 illustrates the size of underserved settlement clusters within southwestern Ontario. The majority of the clusters are "hamlet" and "small-village" sized, but a handful of "large-villages" (501–1000 premises) and "towns" (>1000 premises) remained underserved. If size and density could be used to predict the likelihood of investment by service providers, then market forces would have helped expand basic services availability to these communities.

To illustrate why broadband gaps, data and mapping challenges arise, Figs. 7–10 represent communities from various parts of southwestern Ontario that overlay 2019 National Broadband Internet Service Availability Map data. These visualizations illustrate the variations of availability of service, highlighting the edge of areas where services at speeds that meet the CRTC basic service targets are on offer, as well as human population clusters erroneously considered "served" due to excessive aggregation of local data on available Internet subscription plans.

To further illustrate this situation, Fig. 11 provides another lower-level visualization that exemplifies this problem around one such settlement by combining SWIFT's service offer and premise location data (2019) with data from the National Broadband Internet Service Availability Map (also as of 2019). As this picture demonstrates, the hexagonal approach arbitrarily expands the extent of served/ineligible areas beyond their true boundaries. The bright/translucent lines are the extent of areas where an Internet service provider offers service packages with speeds that meet or exceed the 50/10 Mbps "basic service" target. The dark hexagons are areas considered served, and therefore, ineligible to apply to the CRTC Broadband Fund. The yellow dots represent residential and business premises. Again, in this view of the data, there is a tendency for hexagonal mapping to exaggerate covered areas and thus the number

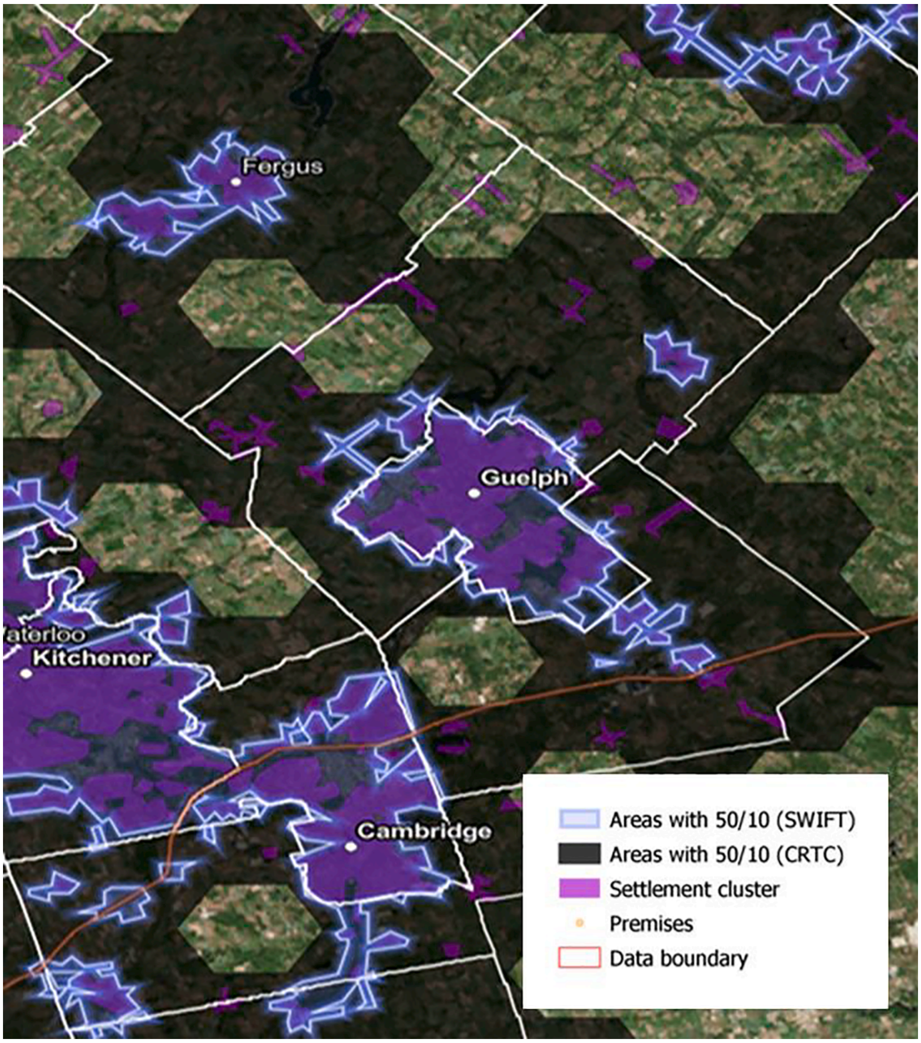

Fig. 8. Availability of basic service broadband: Selected areas in or near Wellingtou County in southwestern Ontario (Source: SWIFT).

of people with access to "basic service" broadband Internet.

Taken altogether, the data and map visualizations (Figs. 7–11) from areas across the southwestern Ontario suggest that certainly in the past, and of concern for on-going investment strategies, the traditional hexagonal approach obscured market failures in the provision of broadband services needed by users that live and work in areas surrounding "served" human population clusters (i.e. the "suburbs" of villages, towns, and cities). This further implicates intra-rural digital divides.

6. Final discussion and conclusions

Rural broadband data may be better generated and directly analyzed within regional initiatives like SWIFT, and aggregated to the national level, rather than a top-down national broadband mapping approach. In this respect, local and dynamic elements can be taken into account in the analysis – for example, the relation of connectivity in census rural areas to the types of connections available regionally, which implicate data on urban and suburban communities. While traditionally used for national (and provincial) planning, national broadband maps risk omissions and inaccuracies that negatively impact fund allocation, project design, and management (including baseline for ex post assessment of project/program outcomes). Furthermore, central governments rely on indicators of availability based on maximum speeds sellers advertise in particular areas, which is not a good proxy for effective service quality levels they deliver or buyers receive in return for their subscription fees. This is particularly the case in rural areas where incentives to make capacity investments as demand grows are limited due to limited revenue potential, a fact that has become particularly evident with the COVID-19 pandemic, stay at home orders, and rapid growth in demand for network resources. In order to develop a more balanced picture that incorporates information from both suppliers and consumers, the methodology must involve triangulation and cross-referencing data from multiple sources, such as user groups (e.g. residents, businesses, farms, public sector, etc.). This calls for a

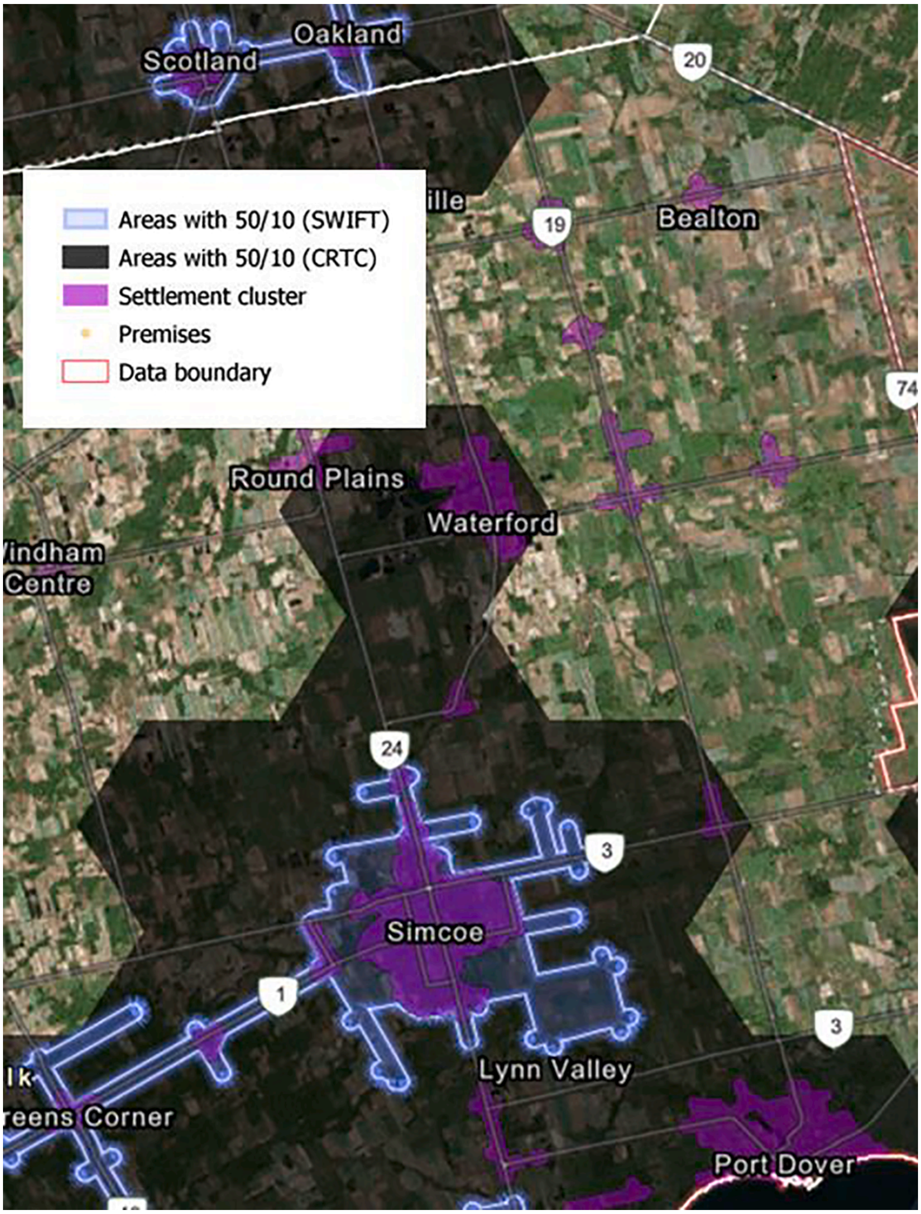

Fig. 9. Availability of basic service broadband: Selected areas in or near Norfolk County in southwestern Ontario (Source: SWIFT).

"bigger and better" data approach to evaluating the state of broadband networks and gaps within rural areas (R2B2, 2019).

"Availability" of shared network capacity is also the outcome of dynamic interaction between supply and demand in local and regional markets. An area that might be considered "served" today may become "underserved" tomorrow if growth in user demand for network resources is higher than the rate by which the infrastructure provider is willing to provision additional capacity over time. Measuring availability based on maximum advertised "up to" rates and advertised Internet speed that is available in a particular area is not capable of accounting for economic dynamics that shape broadband "availability" for users in mature markets such as Canada where access to some form of "high-speed" connectivity is near ubiquitous. For example, the data used in this paper was collected before the start of the COVID-19 pandemic. While suppliers may still be advertising the same speeds as before in particular areas, demand for network resources, reliable, more symmetric services has exploded in both urban and rural areas. In areas where users have access to ultra-high capacity fibre or upgraded cable (i.e. DOCSIS 3.1), people can switch to higher capacity unlimited plans while providers can scale capacity at lower cost. People that depend on congestion prone legacy copper/DSL, wireless, or satellite-based connectivity in rural areas and remote communities do not have this switching capacity and therefore are increasingly disadvantaged in their ability to rebuild their lives in the times of COVID-19.

As network coverage issues have been increasingly solved through public subsidies and private investments over the past two

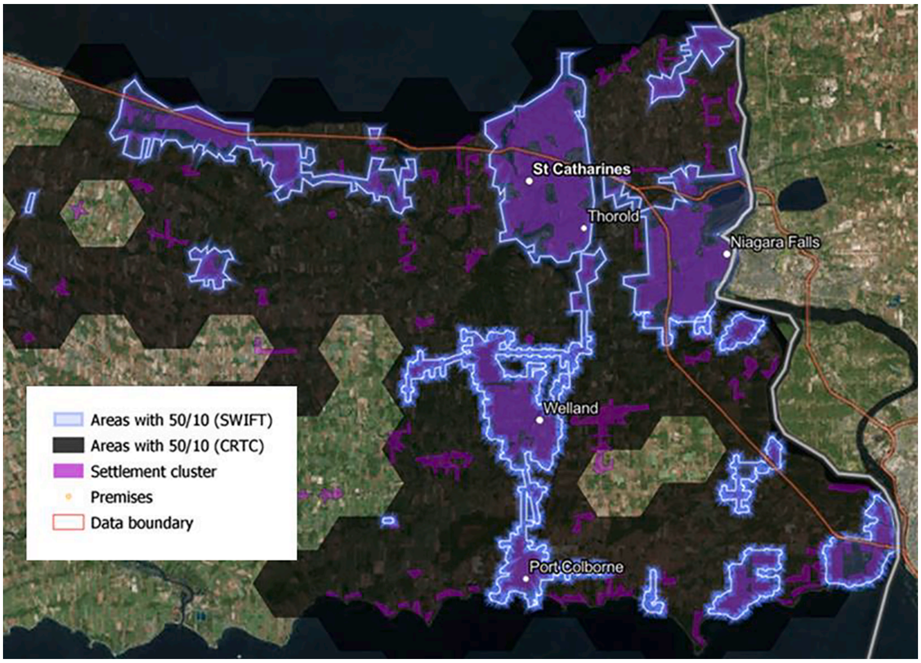

Fig. 10. Availability of basic service broadband: Selected areas in Niagara Region in southwestern Ontario (Source: SWIFT).

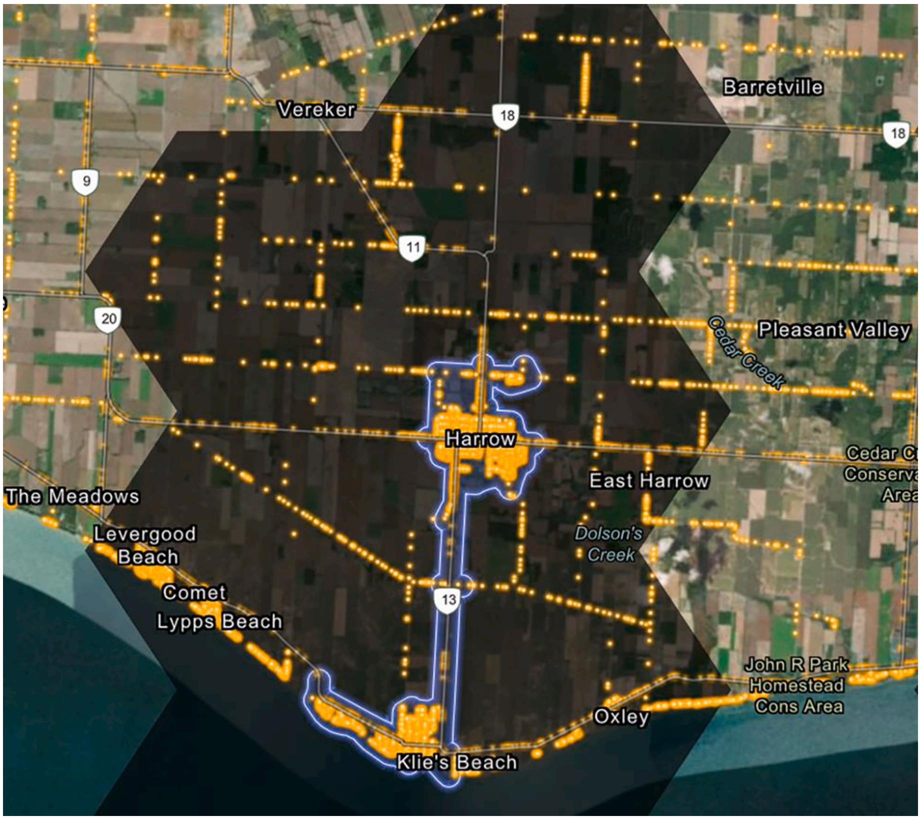

Fig. 11. Illustration of ISED/CRTC hexagonal mapping approach overlaid with basic service broadband coverage data and population data (Source: SWIFT).

decades, there is need to draw in metrics of quality and affordability of services. Learning from studies conducted outside of Canada, a more economic approach should include collecting bigger data that reflects the user experience. Such datasets can significantly enhance the value of the national broadband map as a tool for infrastructure capacity gap identification and investment prioritization for all levels of governments, as well as potential private investors/service providers willing to invest in advanced broadband technologies (e.g. fibre-to-the-premises (FTTP), high throughput 4G+/5G wireless) in underserved communities. In cooperation with data stakeholders such as the Canadian Internet Registration Authority (CIRA) using the M−Lab Network Diagnostic Test (NDT) and the University of Guelph's R2B2 project, Ontario has a growing knowledge base of documentation, crowd-sourced Internet performance tests and user experience data. Growing this knowledge base is important for longitudinal monitoring and impact evaluation purposes, particularly in combination with data from the National Broadband Internet Service Availability Map.

To conclude, further analysis of assumptions identified in the relevant literature about rural digital divides encourages a reconsideration of Canada's approach to broadband Internet access, including ensuring that the traditional hexagonal approach is fully set aside. The regional case from southwestern Ontario combines multiple datasets to call out the evidence-base on which eligibility for public funding and a determination of served, or not, can be defined. Whether or not market forces are "likely" to lead to improvements in rural connectivity and support ecosystem services, rural economies and wider social benefit are empirical questions that should be evaluated closely with better and more data, not just based on advertised or "up to" speeds suppliers claim to offer. Further rural broadband research can provide understanding critical for efficient allocation of scarce public funds, monitoring the performance of subsidy recipients, and enabling accountable service quality delivery to consumers in areas where competition is limited and market forces tend to be weak. The magnitude and distribution of intra-rural broadband gaps relative to, for example, Canada's "basic service" 50/10 Mbps target continues to be important work-in-progress, especially if analysis across various regions of our vast country can be pursued. Possible changes to come were addressed in a keynote presentation to the June 2020 Canadian Rural and Remote Broadband Conference, in which the federal Minister of Rural Economic Development stated that the ISED/CRTC traditional hexagonal mapping approach was being reconsidered. Similarly, the Minister voiced support for broadband as "essential service" to the media (Canadian Broadcasting Corporation, 2020). As part of the pandemic and economic recovery plan Parliament announced on September 23, 2020 accelerated deadlines to implement a new Universal Broadband Fund and more ambitious policy efforts for inclusive connectivity (Government of Canada, 2020).

This paper offers some thoughts on evidence-based decision-making in the design and implementation of rural broadband investment programs, based on experience in Canada, but likely no less relevant for other countries such as the United States where data aggregation by the Federal Communications Commission masks important connectivity gaps (Ali, 2020). The responsibility for overcoming the challenges for evidence-based broadband investment programs lies with the private sector, policymakers, as well as others, including university researchers, to generate, steward, and analyze information that ensures inclusive telecommunications innovation. The market approach can drive a fast and efficient expansion of Internet access, but broadband services within regions and the rural landscape are complex. Federal and provincial averages and generalized approaches to funding hide significant connectivity problems. Expanding reliable, ultra-high capacity broadband networks in regions such as southwestern Ontario is vital in the age of COVID-19 for ensuring that people can continue to work and access essential services such as education and healthcare. The sooner we abandon rural broadband infrastructure investments as "special projects" that address residual gaps left over by market forces, the better. A new era of integrated cellular and broadband network technologies may offer opportunities for rural areas and fill regional gaps, but the longstanding challenge of the data and analytics needed for developing efficient and sustainable rural broadband infrastructure development strategies remain.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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