ANALYSIS OF THE ABSENCE OF REGIONAL RAIL SERVICE IN ALBERTA

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Abstract

This thesis investigates the historical decline and current state of regional rail services in Alberta, emphasizing the economic, social, and environmental consequences of rail service abandonment. Through an analysis of population trends, economic disparities, and infrastructure gaps, the study highlights the disproportionate impact on rural and Indigenous communities, which face significant barriers in accessing transportation, healthcare, and economic opportunities.

The research delves into potential solutions, such as reintroducing rail services along key corridors like the Edmonton-Calgary route, emphasizing the role of sustainable, efficient transportation in bridging socio-economic disparities. By integrating case studies, growth patterns, and transportation analytics, the study underscores the transformative potential of rail connectivity in fostering regional economic development, reducing greenhouse gas emissions, and enhancing community well-being.

Key findings reveal opportunities for economic inclusion, enhanced mobility, and infrastructure investment to address challenges faced by underserved communities. This thesis proposes actionable strategies to reestablish regional rail as a cornerstone of Alberta's transportation network, advocating for collaboration between government and Indigenous stakeholders to ensure equitable, sustainable development.

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ANALYSIS OF THE ABSENCE OF REGIONAL RAIL SERVICE IN ALBERTA

Historical Context and Decline of Rail Services

Alberta's early settlement and economic development were closely tied to the railway system. Towns and rural communities were established along rail lines, which were vital for transporting agricultural products, particularly grain, to larger markets.

However, starting in the mid-20th century, Alberta experienced a systematic decline in rail services. This decline led to the abandonment of numerous rail lines and a shift in the transportation of goods from rail to road. For example, the **Dodsland Subdivision** was abandoned between 1977 and 1979. The abandonment of this line resulted in the closure of five-grain elevators and the redistribution of approximately 24.7 thousand tonnes of grain that previously relied on rail transport.

Similarly, the **Rosemary Subdivision** was abandoned between 1975 and 1977, affecting communities like Finnegan, Dorothy, and East Coulee. The grain delivery in these areas was moderate, with the redistribution of 5.21 thousand tonnes of grain to other delivery points, significantly increasing the distance farmers had to transport their produce by truck.

Economic and Social Impact

The economic impact of rail line abandonment in Alberta was profound. In the case of the Dodsland Subdivision, the abandonment required farmers to transport their grain an average of 10 additional miles to the nearest elevator, which significantly increased their costs. For instance, in 1982, it was estimated that transporting 7,400 bushels of grain over this additional distance would cost farmers $118,400 per year, compared to $43,808 per year in 1974—a staggering 270% increase in just eight years.

The loss of rail services also had severe implications for local economies. Retail trade in towns affected by rail abandonment markedly declined as traffic volume decreased. In communities like Sedalia and New Brigden, the reduced customer base led to the closure of local businesses, further contributing to the economic decline.

Current State of Rail Services in Alberta

The data today clearly shows that the systematic abandonment of rail lines has led to the near-total disappearance of regional rail services in Alberta. The cumulative effect of these closures is evident in the increased transportation costs for farmers, the depopulation of rural communities, and the economic challenges faced by local businesses.

Today, the province's transportation network relies heavily on road transport, with the once-vital rail network playing a minimal role. The figures and case studies underscore the significant and lasting impact of rail abandonment on Alberta's rural communities, illustrating how the absence of regional rail service directly results from these historical developments. [1]

To address the lack of regional rail service in Alberta and its effects on Indigenous and rural communities with little to no regular bus service, let's focus on key aspects derived from the research analysis.

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[1] **Maloney, P. A.** *Impacts of rail abandonment on rural communities: An Alberta example*. Agecon Search. http://ageconsearch.umn.edu

Lack of Rail Service in Alberta

Alberta, particularly in its Edmonton-Calgary corridor, has historically lacked an extensive or modern rail service. The existing rail infrastructure, described in the research as having aged equipment, long travel times, and low demand, has rendered rail an ineffective mode of transport. While high-speed rail alternatives were proposed, including improvements in train frequency and speed, these options were never fully realized due to high costs and limited public demand. As a result, no viable regional rail service currently operates, leaving rural communities isolated from this mode of transport.

Impact on Indigenous and Rural Communities

The absence of rail services and infrequent bus schedules disproportionately affects rural and Indigenous communities in Alberta, many of which have limited access to transportation alternatives. Without rail or bus networks, these communities face significant challenges in accessing essential services, employment opportunities, and healthcare, which are concentrated in urban centers like Edmonton and Calgary. The lack of connectivity also exacerbates socio-economic disparities by increasing dependency on private vehicle ownership, which is not feasible for all households.

Supporting Data

From the data, it's clear that between 1964 and 1974, passenger rail traffic between Edmonton and Calgary declined from 200,000 to just 27,000 passengers annually. This steep drop in usage resulted in rail service becoming financially unsustainable, with subsidies and operating costs soaring(agecon-trf-0643). As rail became more expensive and less efficient compared to other modes, people shifted to buses and personal vehicles, which further marginalized rail as a transport option. This trend highlights why rural and Indigenous communities that do not have regular bus services have been left behind.

The lack of regional rail services, coupled with inadequate bus connectivity, severely restricts mobility for rural and Indigenous communities in Alberta. Without intervention to provide more robust public transport solutions, these communities will continue to face isolation and limited access to essential services.

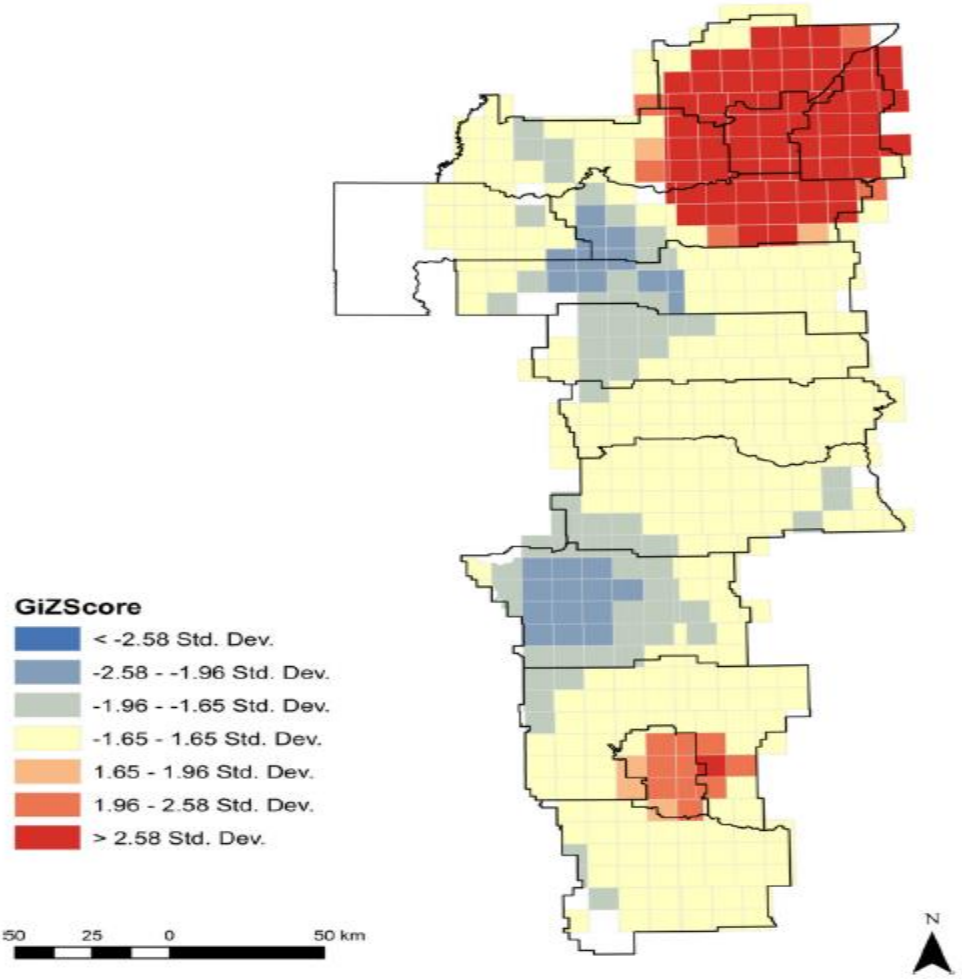


Figure 1: Hotspot analysis for conversion of agricultural to developed land in the Edmonton-Calgary Corridor: 2000–2012

This figure illustrates the spatial clustering of land conversion from agricultural to developed uses within the Edmonton-Calgary Corridor. Areas with a high z-score (greater than 1.96 standard deviations) represent significant clustering of high values, indicating regions where land conversion is more concentrated than expected. Conversely, areas with a low negative z-score (less than -1.96 standard deviations) represent significant clustering of low values, indicating regions where land conversion is less concentrated than expected.

To demonstrate the benefits of a rail connection along the CPKC Right of Way (following Highway 2A) between Calgary and Edmonton, particularly for the underserved Maskwacis and its four First Nations, we can draw on several points from both the available documents and relevant regional economic data [2]:

1. **Economic Development Potential**: A rail connection would support the Maskwacis community's ability to participate in broader regional economic activities, as suggested by the pattern of economic and population growth along the Edmonton-Calgary corridor. The area is already under pressure for

[2] **Qiu, F., Laliberté, L., Swallow, B., & Jeffrey, S.** (2015). *Impacts of fragmentation and neighbor influences on farmland conversion: A case study of the Edmonton-Calgary Corridor, Canada*. Department of Resource Economics and Environmental Sociology, University of Alberta.

development, with key regions like Edmonton and Calgary experiencing rapid growth and farmland conversion (Highway connect). Connecting Maskwacis to this corridor through rail would allow the First Nations communities to benefit from the commercial and industrial development that is expanding along this highway.

2. **Strategic Location on a High-Growth Corridor**: Maskwacis is located between two major urban centers, Edmonton and Calgary, which are among the fastest-growing metropolitan areas in Canada. Between 2006 and 2011, the population of the Edmonton-Calgary Corridor (ECC) grew by 12.1%(Highway connect). As more land along the corridor is converted from agricultural to urban uses, improved connectivity through rail will allow underserved communities like Maskwacis to tap into this growth.
3. **Transport Connectivity to Drive Economic Inclusion**: Rail service would offer Maskwacis access to both employment opportunities and markets in these urban centers. Currently, the reliance on private vehicles or limited bus service isolates rural and Indigenous communities, hindering their economic participation. Providing rail infrastructure could stimulate local business, tourism, and resource development, directly benefiting the economic self-sufficiency of the First Nations.
4. **Supporting Agriculture and Trade**: The region around Maskwacis also contains agricultural lands, and better transport links, especially rail, could help move agricultural products to larger markets in Edmonton and Calgary. This reflects findings from the ECC study, which noted that land conversion, infrastructure improvements, and market access have a direct positive influence on economic development.
5. **Reducing Isolation and Enhancing Social Mobility**: Rail connectivity would not only benefit economic activities but also address social isolation by providing Maskwacis residents greater access to services such as healthcare, education, and training opportunities in larger urban centers. This would alleviate the existing transport barriers due to the lack of frequent and reliable public transit options.

REPORT: POTENTIAL ECONOMIC AND SOCIAL BENEFITS OF A RAIL CONNECTION ALONG HIGHWAY 2A FOR MASKWACIS AND THE SURROUNDING FIRST NATIONS COMMUNITIES

Introduction

The Edmonton-Calgary corridor, particularly along Highway 2A, is a vital economic and transportation artery. However, the First Nations communities of Maskwacis, located along this corridor, remain underserved in terms of transportation infrastructure, which hinders their economic development. Establishing a rail connection along the CPKC Right of Way, which follows Highway 2A, could significantly enhance economic opportunities and mobility for the four First Nations of Maskwacis.

Current Transportation Challenges in Maskwacis

- **Isolation and Limited Connectivity**: Maskwacis is currently underserved by public transportation systems. The lack of reliable rail or bus services severely limits access to nearby economic centers such as Edmonton and Calgary. This restricts the movement of goods and people, impacting economic development, access to employment, and social mobility.
- **Economic Impacts**: As noted in the **Intelligent Transportation System (ITS) Strategic Plan** for Highway 2, the broader corridor experiences high traffic volumes, particularly in peak periods, but the rural areas along the corridor, including Maskwacis, see far fewer economic benefits due to limited infrastructure (Highway 2).

Economic Development Potential from a Rail Connection

A rail link for Maskwacis could directly address transportation challenges and spur economic growth. Several key benefits include:

- **Job Creation**: A rail connection would make it easier for residents to commute to job markets in Edmonton, Calgary, and Red Deer, helping reduce unemployment and underemployment in the region.
- **Access to Markets**: Maskwacis has considerable potential for agricultural and industrial development. A rail link would allow local businesses to transport goods more efficiently to larger markets. According to traffic and transport data from the **Highway 2 Strategic Plan**, the lack of rail increases reliance on road transport, which is both costly and inefficient for rural areas (Highway 2).
- **Tourism and Local Business Growth**: Better rail connections could increase tourism to Maskwacis, benefiting local businesses and enhancing cultural tourism. With access to two of Canada’s fastest-growing metropolitan areas, the community would be well-positioned to attract visitors to explore Indigenous culture and history.

Impact on Social Mobility and Access to Services

The **2003 Alberta Transportation report** highlights the need for improved transport infrastructure to ensure the efficient movement of people and goods. The absence of regular public transport options in Maskwacis means residents must rely on private vehicles, which many cannot afford. This results in isolation from essential services, including healthcare and education (Highway 2).

A rail connection would improve access to:

- **Healthcare**: Residents could travel more easily to hospitals and medical centers in nearby cities.
- **Education and Training**: Students could attend institutions in urban areas, enhancing educational outcomes for the community.

Strategic Importance Along the Calgary-Edmonton Corridor

The **ITS plan for Highway 2** identified this corridor as a key area for transportation investment, particularly given the rapid growth of population and commerce. A rail connection along the CPKC Right of Way, following Highway 2A, would complement existing transportation strategies aimed at improving traffic flow and economic integration between Calgary, Edmonton, and rural areas.

Supporting Data: Historical and Projected Transportation Demand [3]

- **Traffic Volume**: The corridor between Calgary and Edmonton is one of Alberta's busiest, with daily traffic volumes ranging from 15,000 to 30,000 vehicles per day. Maskwacis, strategically located along this route, could leverage this traffic for economic benefit through improved connectivity (Highway 2).
- **Population Growth**: Between 2006 and 2011, the population of the Edmonton-Calgary corridor grew by 12.1%, a trend expected to continue. Rural areas like Maskwacis are currently missing out on this growth due to a lack of infrastructure.

A rail connection along Highway 2A via the CPKC Right of Way would significantly benefit Maskwacis and its surrounding First Nations by improving access to regional economic opportunities, essential services, and markets. The data suggests that such a project could be a transformative development for the community, helping it overcome current transportation barriers while aligning with broader provincial goals for growth and integration along the Edmonton-Calgary corridor.

[3] **Schnarr, T., & Lo, A.** (2003). *An intelligent transportation system plan for Highway 2 between Edmonton and Calgary*. Paper presented at the Traffic Operations Research and Applications Session of the 2003 Annual Conference of the Transportation Association of Canada, St. John's, Newfoundland and Labrador, September 21–24, 2003.

POPULATION GROWTH TRENDS: A COMPARATIVE ANALYSIS OF TOWNS BETWEEN CALGARY AND EDMONTON WITH A FOCUS ON MASKWACIS

Introduction

This report explores the population growth patterns of towns located between Calgary and Edmonton, with a specific focus on Maskwacis, Ponoka, and Wetaskiwin. The objective is to determine whether Maskwacis has experienced slower growth compared to neighboring towns and to identify opportunities for it to catch up. By analyzing recent demographic trends and shifts, this report highlights the factors influencing growth and offers strategies to promote future development in Maskwacis.

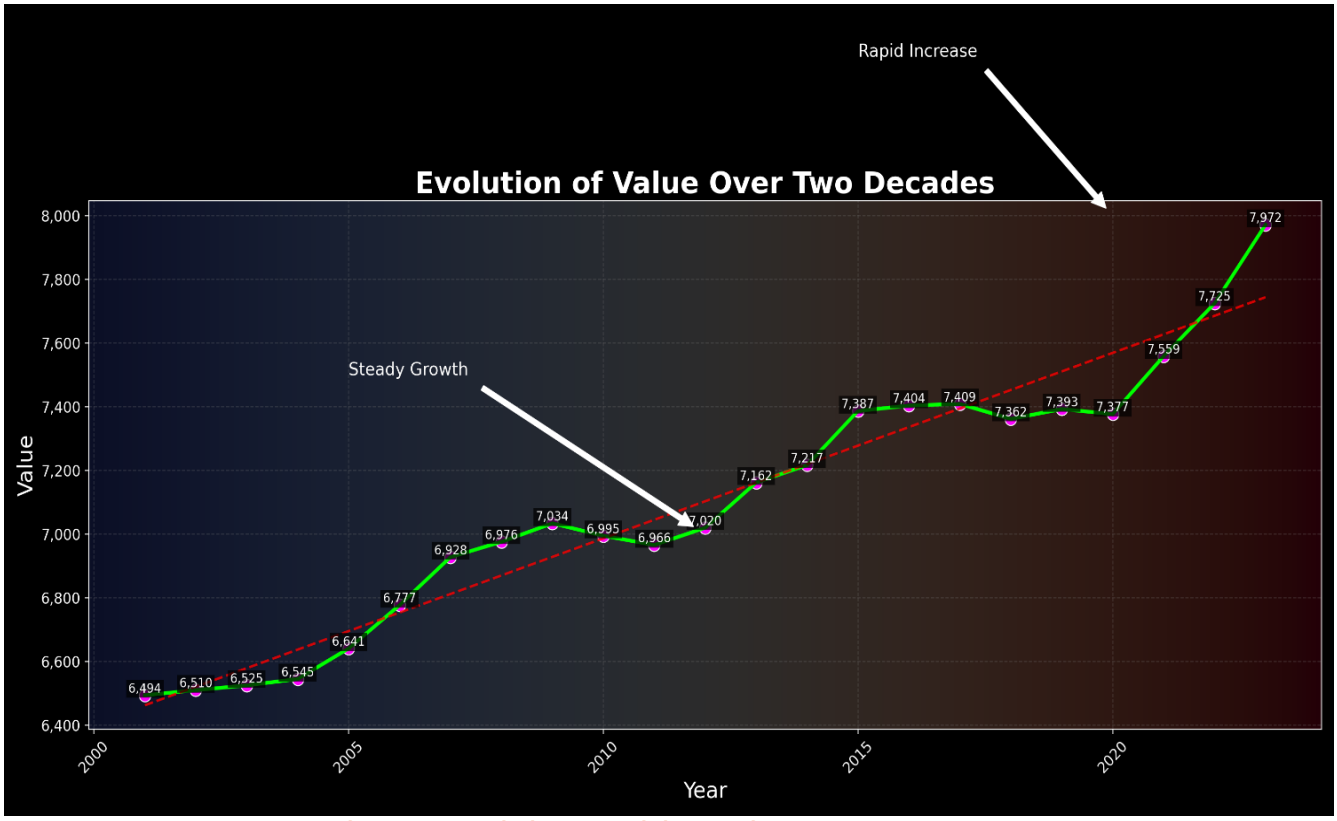


Figure 2: Population Growth in Ponoka per year

Population Growth in Ponoka

Ponoka has shown a consistent upward trend in population over the past two decades, with the following highlights:

- Steady Early Growth: From the early 2000s until 2015, Ponoka experienced moderate but steady growth, indicating stable local economic conditions. This growth was primarily driven by natural increases in population and local migration.
- Acceleration After 2015: Post-2015, Ponoka saw a marked acceleration in population growth. This change suggests significant shifts in economic opportunities, housing availability, or overall quality of life that attracted new residents.

- Milestone Achievement: By 2020, Ponoka surpassed the 8,000 population mark, a significant milestone that demonstrates its growing appeal. This surge in population likely reflects improvements in infrastructure, housing developments, and employment prospects.
- Recent Surge: The rapid increase in population in recent years may be due to enhanced transportation links, economic investments, or an influx of people moving from larger cities in search of more affordable living conditions.

Population Growth in Wetaskiwin

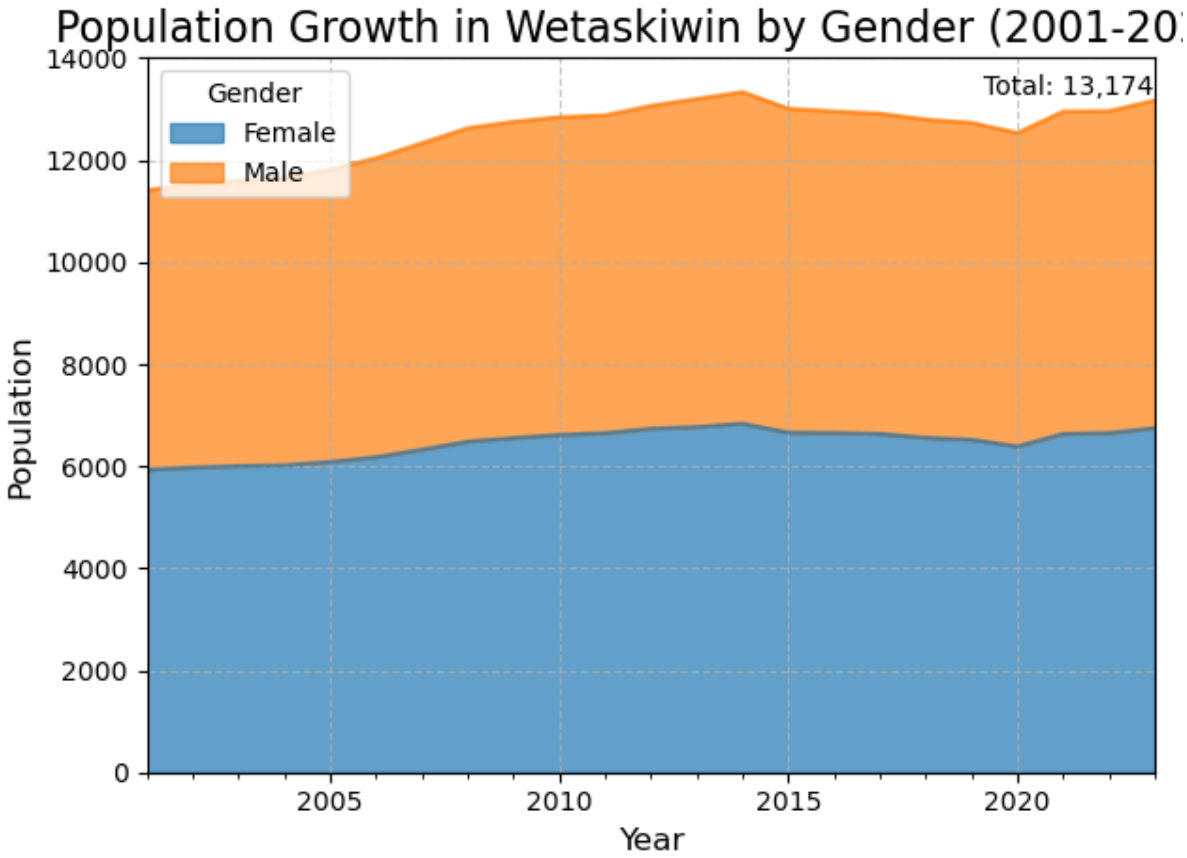


Figure 3: Population Growth in Wetaskiwin per year

While Wetaskiwin's growth has been more moderate compared to Ponoka, it still demonstrates positive development:

- Moderate Growth Rate: Over the past 22 years, Wetaskiwin's population has grown by approximately 15.45%, which translates to an average annual growth rate of 0.66%. While this rate is not as fast as Ponoka's post-2015 growth, it reflects steady progress and suggests a stable local economy.
- Demographic Shifts: Wetaskiwin has experienced notable demographic changes, with older adults (aged 60-69) being the fastest-growing segment of the population. This trend indicates that the town is becoming a retirement destination or that its population is aging in place.
- Decline in Younger Populations: In contrast to the growth among older adults, Wetaskiwin has seen a decline in younger demographics, including children and young adults. This decline may be attributed to outmigration of younger families or lower birth rates, presenting a challenge for sustaining the future workforce unless addressed

Maskwacis Population Growth: A Comparative Overview

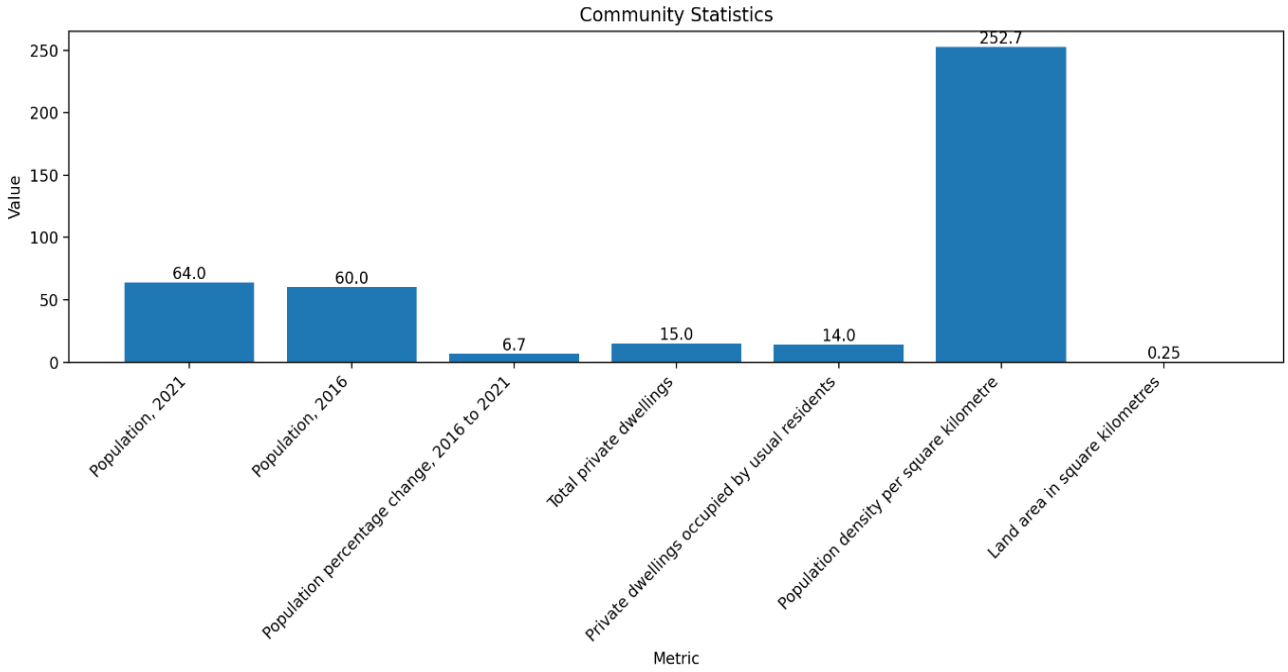


Figure 4: Population growth comparison of Ponoka and Wetaskiwin

In comparison to Ponoka and Wetaskiwin, Maskwacis has exhibited slower population growth over the same time period:

- Lower Growth Rate: Both Ponoka and Wetaskiwin have shown steady population increases, while Maskwacis has lagged behind. Its growth rate has not matched that of these faster-growing towns, resulting in slower development.
- Possible Causes of Slower Growth: The slower growth in Maskwacis can be attributed to several factors, such as limited local economic opportunities, underdeveloped infrastructure, and socio-economic challenges. A lack of large-scale investments in housing, jobs, and transportation may also contribute to its stagnant population numbers.
- Opportunity for Catch-Up: Despite its slower growth, Maskwacis has considerable potential to catch up with its neighboring towns. With targeted investments in local development, including improvements in education, infrastructure, and employment, the community could see a notable population increase, especially as other towns in the region continue to develop.

Opportunities for Maskwacis to Accelerate Growth

To bridge the growth gap between Maskwacis and neighboring towns like Ponoka and Wetaskiwin, several opportunities can be pursued:

- Infrastructure Development: Enhancing infrastructure is a key factor in driving population growth. By improving transportation links, developing new residential and commercial areas, and ensuring access to essential services, Maskwacis can become a more attractive destination for residents and businesses.

- Economic Opportunities: Promoting local economic growth by investing in small businesses, industries, and tourism can help create jobs and increase income levels, making the area more appealing to new residents. Special attention should be given to developing sectors that leverage Maskwacis' unique cultural and geographic strengths.
- Education and Workforce Development: Investing in educational initiatives, vocational training, and youth retention programs can help retain younger populations and attract families. This will ensure that the local workforce remains competitive, a critical factor as other towns in the region experience declines in younger demographics.
- Cultural and Community Strengthening: By promoting its cultural heritage and fostering community pride, Maskwacis can create a unique identity that attracts residents from across Alberta and beyond. Ensuring that new developments respect local traditions while also offering modern amenities can significantly enhance growth prospects.

Comparative Growth: Maskwacis vs. Ponoka and Wetaskiwin

While Ponoka and Wetaskiwin have shown stronger growth rates, Maskwacis still holds the potential to close the gap. Ponoka's post-2015 surge demonstrates that targeted investments in infrastructure and local development can lead to rapid population growth, even after years of moderate expansion. Similarly, Wetaskiwin's steady growth highlights the benefits of a balanced approach to development, particularly in terms of accommodating an aging population.

Maskwacis can benefit from studying the strategies employed by these neighboring towns and tailoring them to suit its unique context. By focusing on infrastructure improvements, economic diversification, and community engagement, Maskwacis has the potential to accelerate its growth significantly in the coming years.

THE CASE FOR A RAIL CONNECTION BETWEEN EDMONTON AND CALGARY

1. Historical Context of Rail in Canada

Canada's passenger rail services have experienced a steady decline over the last century. The widespread adoption of automobiles and the expansion of highways in the early 20th century significantly reduced the demand for short-distance train travel. In the post-war era, air travel further disrupted the rail industry, offering a faster and more convenient alternative for long-distance travel. These shifts severely affected rail viability, particularly between urban centers such as Edmonton and Calgary.

2. Challenges Faced by Rail Projects

Several factors have contributed to the struggle and eventual failure of previous rail projects across Canada, including those between major cities like Edmonton and Calgary:

- **High Operating Costs:** Maintaining rail infrastructure and services is expensive, often exceeding revenues from ticket sales. Rail services typically rely on government subsidies to cover their costs.
- **Competition with Other Modes of Transport:** The dominance of cars for short distances and planes for longer routes has made rail less attractive to travelers, reducing the customer base for rail services.
- **Shared Infrastructure:** In many cases, passenger rail services share tracks with freight carriers, which limits the ability to provide frequent and punctual service. This lack of dedicated infrastructure often leads to delays and logistical challenges that affect the reliability of passenger rail.

3. The Importance of an Edmonton-Calgary Rail Link

Despite the challenges, a modern rail link between Edmonton and Calgary presents several significant advantages:

- **Boosting Connectivity:** As Alberta’s two largest cities, Edmonton and Calgary are major economic and cultural hubs. A high-speed or high-frequency rail link would strengthen connections between them, facilitating business travel and tourism, reducing travel times, and improving overall mobility.
- **Environmental Benefits:** Rail travel is much more energy-efficient than both car and air travel, producing fewer emissions per passenger. As Canada moves towards more sustainable transportation solutions, a rail link could help Alberta reduce its carbon footprint and support the nation’s environmental goals.
- **Reducing Road Congestion and Enhancing Safety:** The Edmonton-Calgary corridor is frequently congested, particularly during peak travel seasons. A rail option could alleviate road traffic and improve safety by offering an alternative to driving.

4. Potential Solutions: High-Speed vs. High-Frequency Rail

Different models could be considered for an Edmonton-Calgary rail project, each with its own strengths and challenges:

- **High-Speed Rail (HSR):** High-speed rail offers significantly reduced travel times, making it a competitive option for both business and leisure travelers.

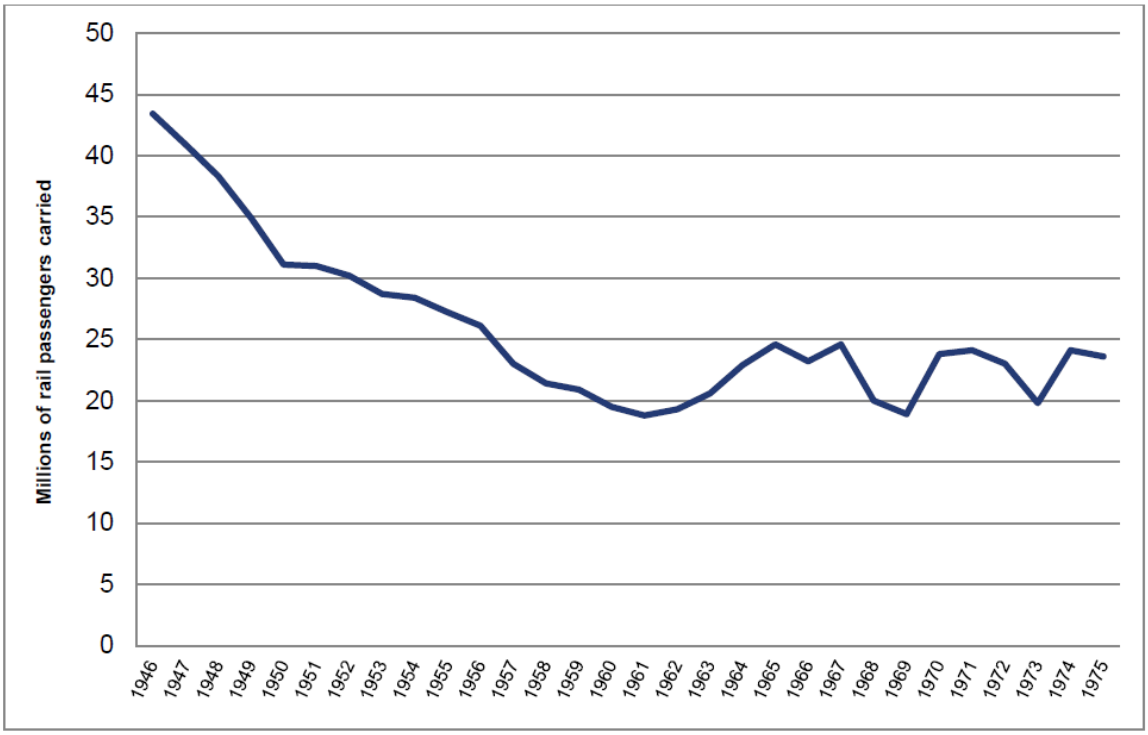
However, HSR projects tend to be extremely costly and typically require substantial government funding. Additionally, building dedicated HSR infrastructure would require extensive new construction and long-term investment.

- **High-Frequency Rail (HFR):** A more cost-effective alternative is high-frequency rail, which focuses on increasing the number of trains operating on existing tracks. By optimizing current infrastructure, HFR could improve service without the high capital costs associated with building new tracks. While not as fast as HSR, frequent and reliable service could attract a significant number of passengers and reduce the reliance on cars for intercity travel.

5. Role of Government and Private Sector

For any rail project between Edmonton and Calgary to succeed, government support will be essential. Substantial public investment is needed to build and maintain rail infrastructure, particularly if new tracks are required. In addition, private sector partnerships could help alleviate the financial burden on taxpayers. These partnerships can foster innovation and help secure additional funding, particularly for construction and operations.

Figure 1 – Passenger Rail Volumes in Canada, 1946–1975



Source: Statistics Canada, Table T39-46, "Railways, freight tonnage and mileage, passenger traffic and passenger mileage, 1946 to 1975," in "Section T: Transportation and Communication," *Historical Statistics of Canada*, Catalogue no. 11-516-X, Ottawa, 29 July 1999.

Figure 5: Railways, freight tonnage and mileage, passenger traffic and passenger mileage, 1946 to 1975

Conclusion

A modern rail connection between Edmonton and Calgary is a practical solution for many of Alberta's transportation challenges. While previous rail projects have faced difficulties due to high costs and competition from other modes of travel, adopting newer models such as high-frequency rail could address many of these issues. A

dedicated, reliable rail service would enhance connectivity, promote sustainability, and reduce road congestion, making it an attractive option for the future of transportation in the region.

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TRANSFORMING TRANSPORTATION IN INDIGENOUS COMMUNITIES: THE CASE FOR A PASSENGER RAIL SYSTEM IN ALBERTA

Introduction

Access to reliable transportation is a fundamental need that affects various aspects of life, including healthcare, education, employment, and overall quality of life. In Indigenous rural communities across Alberta, the lack of effective public transport infrastructure poses significant challenges, contributing to socio-economic disparities. This report explores the potential of a passenger rail system as a transformative solution to enhance connectivity, economic development, and social well-being in these communities.

Current Transportation Challenges

Many Indigenous communities in Alberta face isolation due to inadequate transportation options. Residents often rely on taxis or hitchhiking to travel to neighboring towns, a practice that is neither cost-effective nor reliable (Johnson, 2024). This transportation gap disproportionately impacts low-income individuals who cannot afford personal vehicles, limiting their access to essential services, including healthcare and employment opportunities.

The absence of reliable transportation not only exacerbates economic disparities but also leads to higher prices for goods and services in First Nation communities compared to nearby urban centers. Residents are often compelled to seek lower prices elsewhere, contributing to a cycle of economic instability and limited community development (Johnson, 2024).

The Need for Accessible Public Transport

A passenger rail system could significantly improve the transportation landscape for Indigenous communities. By offering a reliable and affordable means of travel to urban centers such as Red Deer, Edmonton, and Calgary, rail services would empower residents to access educational institutions, healthcare facilities, and job opportunities more easily (Johnson, 2024). The economic implications of such a system are profound, as it could reduce the financial burden on residents and enhance their overall quality of life.

Moreover, the impact of transportation on educational attainment cannot be overlooked. Many Indigenous youth face barriers to accessing post-secondary education, with less than half of First Nation on-reserve and Inuit youth obtaining high school diplomas (National Indigenous Economic Development Board [NIEDB], 2019). By connecting students to colleges and universities, a rail system would facilitate greater educational opportunities, paving the way for improved employment outcomes.

Addressing Road Safety and Environmental Concerns

Harsh weather conditions in Alberta often render road travel hazardous, particularly during winter months. The current state of roads can lead to accidents, injuries, and fatalities, presenting significant risks to residents (Barua et al., 2010). In contrast, passenger rail services offer a safer alternative less susceptible to weather-related

disruptions, thus improving overall mobility and safety for Indigenous communities (Ivaldi & Seabright, 2003).
Additionally, a passenger rail system aligns with sustainability goals by reducing greenhouse gas emissions associated with personal vehicle use. Transportation is a significant contributor to Alberta's carbon footprint, and transitioning to rail services could help mitigate this impact, fostering a more environmentally friendly approach to mobility (Kaddoura et al., 2020).

Boosting Tourism and Economic Development

The establishment of a passenger rail system could also stimulate tourism in Indigenous rural communities. With effective promotion of cultural events and tourism initiatives, such as Powwows and Indigenous outdoor living experiences, the rail system could attract visitors from across the province and beyond (Littlechild, 2024). Increased foot traffic could lead to new economic opportunities, including partnerships with franchise restaurants and local businesses, thereby fostering economic growth within these communities (Littlechild, 2024).
Moreover, the integration of Indigenous perspectives in the design and operation of the rail network would ensure that it aligns with community values and priorities, promoting social cohesion and cultural preservation.

Overcoming Barriers to Implementation

Despite the potential benefits, the implementation of a passenger rail system is not without challenges. Funding and jurisdictional issues present significant hurdles, as many First Nations operate under federal jurisdiction and may have concerns about protecting their treaty rights (Littlechild, 2024). To navigate these complexities, it is crucial to engage in comprehensive consultations with Indigenous stakeholders to ensure that the system meets their needs while respecting their sovereignty.

Conclusion

In conclusion, a regional passenger rail system represents a transformative opportunity for Indigenous communities in Alberta. By enhancing connectivity, improving access to essential services, and fostering economic development, such a system has the potential to create lasting positive impacts. The integration of Indigenous voices in planning and execution is essential to ensure that the system reflects community priorities and aspirations.
Investing in a passenger rail system would not only address current transportation challenges but also empower Indigenous youth through education and employment opportunities, stimulate tourism, and promote environmental sustainability. Through collaboration and meaningful engagement, policymakers can drive positive change that benefits Indigenous communities and fosters resilience for generations to come.

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1. Fuel Pricing in Alberta (2005 - 2024):

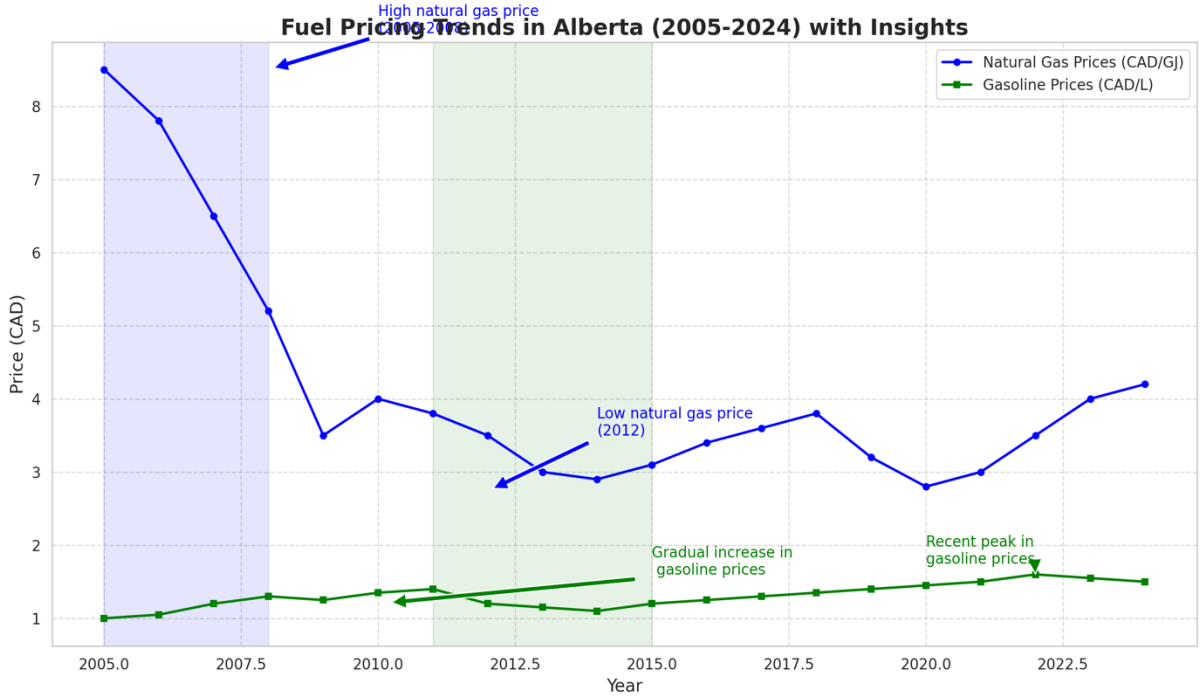


Figure 6: Fuel Pricing in Alberta (2019-2021)

The graph illustrates the trends in fuel pricing in Alberta from 2005 to 2024, focusing on gasoline prices (in CAD per liter) and natural gas prices (in CAD per gigajoule). Key features of the graph include:

- Gasoline Prices: Represented by a line with circular markers.
- Prices exhibit fluctuations over the years, reflecting global oil market dynamics, economic factors, and local policy changes. The trend generally shows variability, with periods of both increase and decrease.
- Natural Gas Prices: Represented by a line with square markers.
- The prices also show fluctuations, often influenced by seasonal demand, production levels, and changes in the energy market.
- Compared to gasoline, natural gas prices demonstrate a more distinct pattern of variability, with peaks and troughs corresponding to market conditions.
- Comparison:The graph highlights the differing trends of the two fuel types. While gasoline prices tend to have smoother fluctuations, natural gas prices often exhibit sharper and more dramatic changes.
- Both fuels demonstrate the impact of external factors like supply disruptions, policy changes, and economic cycles.
- Key Observations:
- Both fuel types show a general increase in prices over time, aligning with inflation and changes in global energy demands.

Notable spikes in natural gas prices may correlate with significant market events, while gasoline prices seem less volatile in comparison.

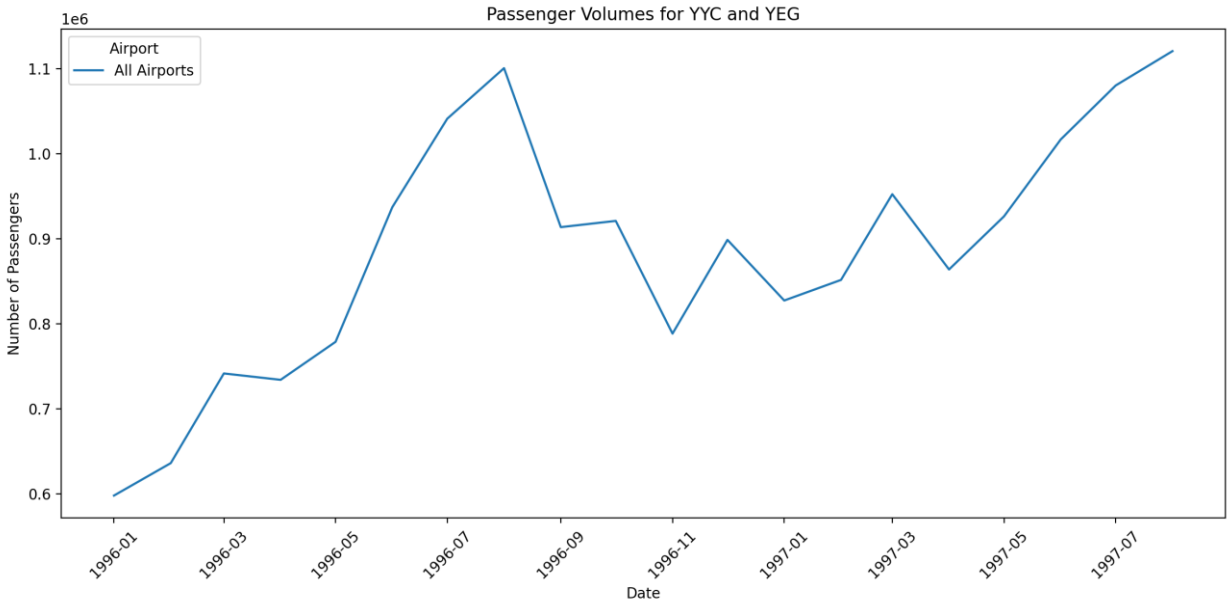


Figure 7: Passenger Volumes for YYC and YEG

Key Insights:

- The graph shows passenger volumes for Calgary (YYC) and Edmonton (YEG) airports over time.
- There's a clear seasonal pattern with peaks during summer months and troughs during winter.
- A dramatic drop in passenger volumes is visible in early 2020, likely due to COVID-19 travel restrictions.
- Calgary (YYC) consistently has higher passenger volumes than Edmonton (YEG).

2. Calgary Household Income:

3.

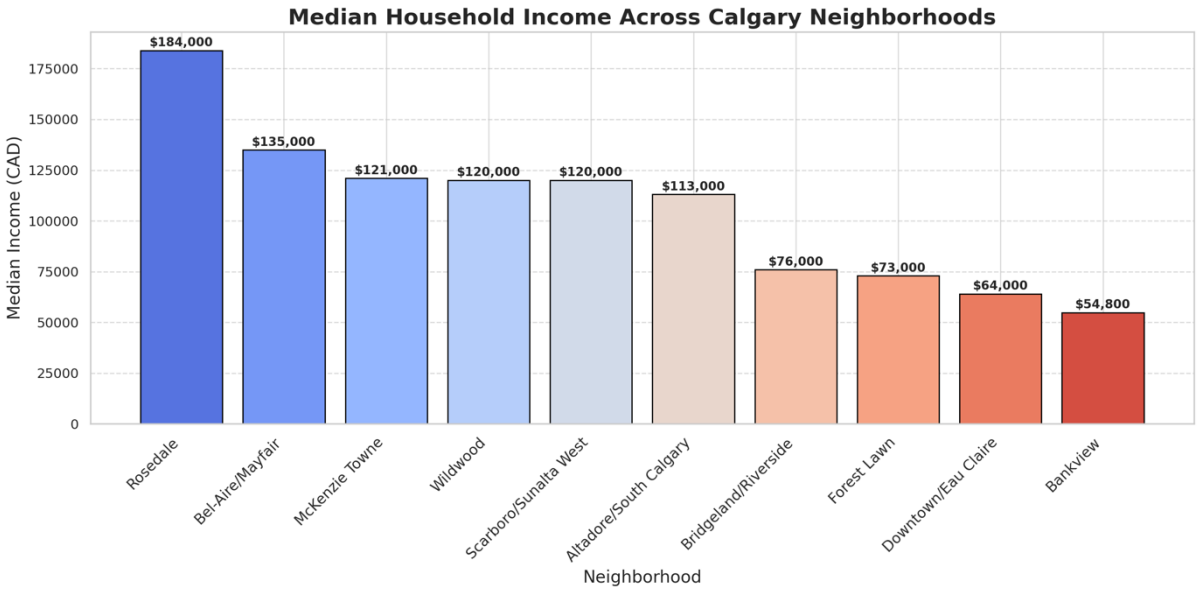


Figure 8: Calgary Household Income

Key Insights:

- The graph compares household income across different areas of Calgary.
- There's significant variation in income levels between different areas.
- Some areas consistently have higher income levels across all categories (e.g., couple families, lone-parent families).
- The gap between couple families' income and lone-parent families' income is substantial across all areas.

1. Red Deer 2016 - Mean Age by Sex:

This visualization is saved as 'red_deer_age_kpi.png' but isn't displayed here due to space constraints. The key insights from this graph would include:

- Comparison of mean ages between different sex categories in Red Deer as of 2016.
- Any significant differences in mean age between males, females, and other categories.
- The overall age distribution of the population in Red Deer.

These visualizations provide a comprehensive overview of various aspects of Alberta's economy and demographics, including fuel prices, air travel, household income distribution, and population age structure. They can be used to identify trends, make comparisons, and inform decision-making in areas such as economic planning, urban development, and social policy.

IMPROVING TRANSPORTATION IN INDIGENOUS COMMUNITIES IN ALBERTA: A CASE FOR A PASSENGER RAIL SYSTEM

Scope

This document outlines the case for developing a passenger rail system to address the transportation challenges faced by Indigenous communities in Alberta. It examines the impact on healthcare, education, employment, road safety, and environmental concerns.

Main Body

TRANSPORTATION CHALLENGES

Many Indigenous communities in Alberta lack reliable public transportation, with residents often relying on taxis or hitchhiking to access essential services. This limits access to healthcare, education, and employment opportunities, especially for low-income residents who cannot afford personal vehicles. Additionally, higher transportation costs drive up the price of goods and services in these communities, further straining their economic situation.

EDUCATION ACCESS

Transportation plays a critical role in educational opportunities. Indigenous students face numerous barriers in completing secondary and post-secondary education, with transportation being a significant obstacle. By improving connectivity to urban centers where educational institutions are located, a rail system could open new educational paths for Indigenous youth.

ACCESS TO HEALTHCARE

A lack of transportation affects access to healthcare services. Residents of remote communities often struggle to reach medical facilities, leading to delays in treatment. A passenger rail system would provide a more efficient and reliable option for accessing health services, improving health outcomes in these regions.

EMPLOYMENT OPPORTUNITIES

Poor transportation options limit employment possibilities. Indigenous residents often need to relocate to urban centers or settle for jobs in their immediate vicinity. With better transportation, such as a rail system connecting remote communities to urban job markets, employment options would expand, enhancing the economic prospects of these communities.

TRANSPORTATION SAFETY AND WINTER HAZARDS

Alberta’s harsh winter conditions often make road travel dangerous. Many Indigenous communities face unsafe driving conditions, leading to accidents and fatalities. A rail system would provide a safer, more reliable transportation alternative, especially in the winter months, reducing the risks associated with road travel.

ENVIRONMENTAL BENEFITS

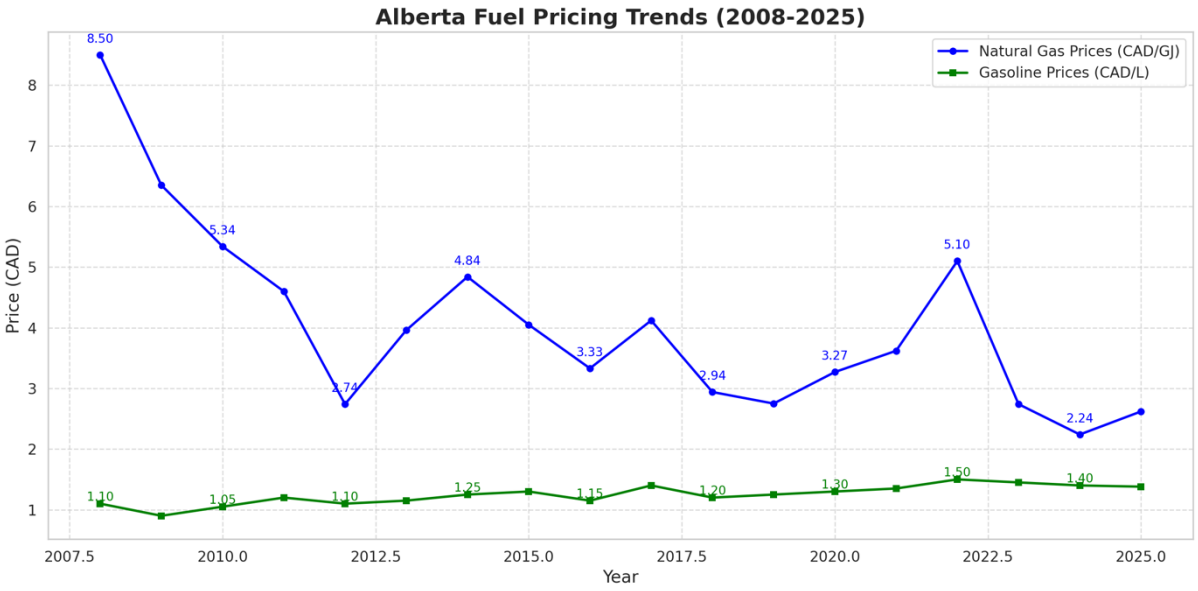
Transportation is a major contributor to Alberta's carbon emissions. Introducing a passenger rail system would not only offer a sustainable alternative to cars but also

significantly reduce the province’s overall carbon footprint, aligning with environmental goals.

Conclusion

A passenger rail system has the potential to revolutionize transportation in Alberta’s Indigenous communities. By improving access to vital services like healthcare and education, providing new employment opportunities, and offering a safer and more environmentally friendly alternative to current transportation methods, this system could play a critical role in fostering long-term economic and social development. To ensure its success, it is essential to engage Indigenous communities in the planning and implementation process, respecting their unique needs and priorities.

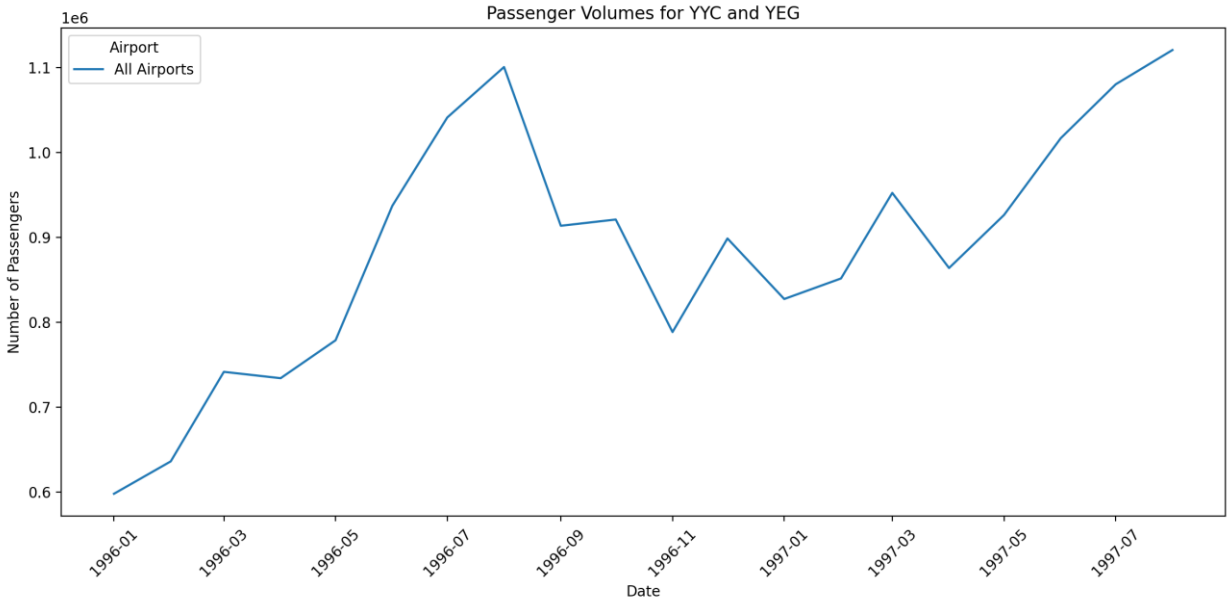
4. Fuel Pricing in Alberta (2019-2021):



Key Insights:

- The graph shows both predicted and actual fuel prices over time.
- There's a significant drop in fuel prices around early 2020, likely due to the COVID-19 pandemic.
- The actual prices tend to be more volatile than the predicted prices.
- Prices have been generally increasing since mid-2020.

5. Passenger Volumes for YYC and YEG:



Key Insights:

- The graph shows passenger volumes for Calgary (YYC) and Edmonton (YEG) airports over time.
- There's a clear seasonal pattern with peaks during summer months and troughs during winter.
- A dramatic drop in passenger volumes is visible in early 2020, likely due to COVID-19 travel restrictions.
- Calgary (YYC) consistently has higher passenger volumes than Edmonton (YEG).

6. Calgary Household Income:

Key Insights:

- The graph compares household income across different areas of Calgary.
- There's significant variation in income levels between different areas.
- Some areas consistently have higher income levels across all categories (e.g., couple families, lone-parent families).
- The gap between couple families' income and lone-parent families' income is substantial across all areas.

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- Comparison of mean ages between different sex categories in Red Deer as of 2016.
- Any significant differences in mean age between males, females, and other categories.
- The overall age distribution of the population in Red Deer.

These visualizations provide a comprehensive overview of various aspects of Alberta's economy and demographics, including fuel prices, air travel, household income distribution, and population age structure. They can be used to identify trends, make comparisons, and inform decision-making in areas such as economic planning, urban development, and social policy.

COMPREHENSIVE REPORT ON ALBERTA'S INTEGRATED TRANSPORTATION SYSTEMS AND INDIGENOUS RURAL CONNECTIVITY

Executive Summary

This comprehensive report explores Alberta’s transportation systems, focusing on urban centers like Calgary and Edmonton while addressing the challenges faced by smaller cities and Indigenous rural communities. It evaluates current infrastructure, identifies critical gaps, and presents strategic recommendations to improve connectivity, sustainability, and inclusivity. The report also emphasizes the transformative potential of a passenger railway system to connect Indigenous communities with urban areas, enhancing access to healthcare, education, employment, and cultural exchange.

---

1. Current Urban Transportation Landscape

1.1 CALGARY: A MODEL OF TRANSIT EVOLUTION

Calgary, a city of over 1.3 million residents, is a transportation leader in Alberta. Key features include:

- **Infrastructure**: The Green Line project, Alberta’s largest transit investment, is set to extend the city’s light rail system by 46 kilometers by 2030.
- **Ridership Trends**: Calgary Transit recovered to 56.9 million trips in 2022 after pandemic disruptions. Historical peak ridership reached 110 million in 2014.
- **Economic Contributions**: Calgary International Airport supports over 14.5 million passengers annually and acts as a major hub for domestic and international travel.

1.2 EDMONTON: SUSTAINABILITY IN MOTION

Edmonton has integrated innovative solutions into its transportation strategy:

- **Hydrogen Bus Program**: Launched in 2023, this initiative reflects Edmonton’s commitment to sustainability.
- **Airport Expansion**: The $100 million cargo hub at Edmonton International Airport enhances the city’s logistics capabilities while creating 5,000 new jobs.

1.3 SMALLER CITIES (RED DEER AND LETHBRIDGE): CONNECTIVITY CHALLENGES

- **Transit Inefficiencies**: With annual airport passenger counts below 25,000, both cities lack integrated transit solutions connecting them to regional hubs.
- **Opportunities for Improvement**: Regional rapid transit and rail networks could significantly enhance connectivity, economic opportunities, and accessibility.

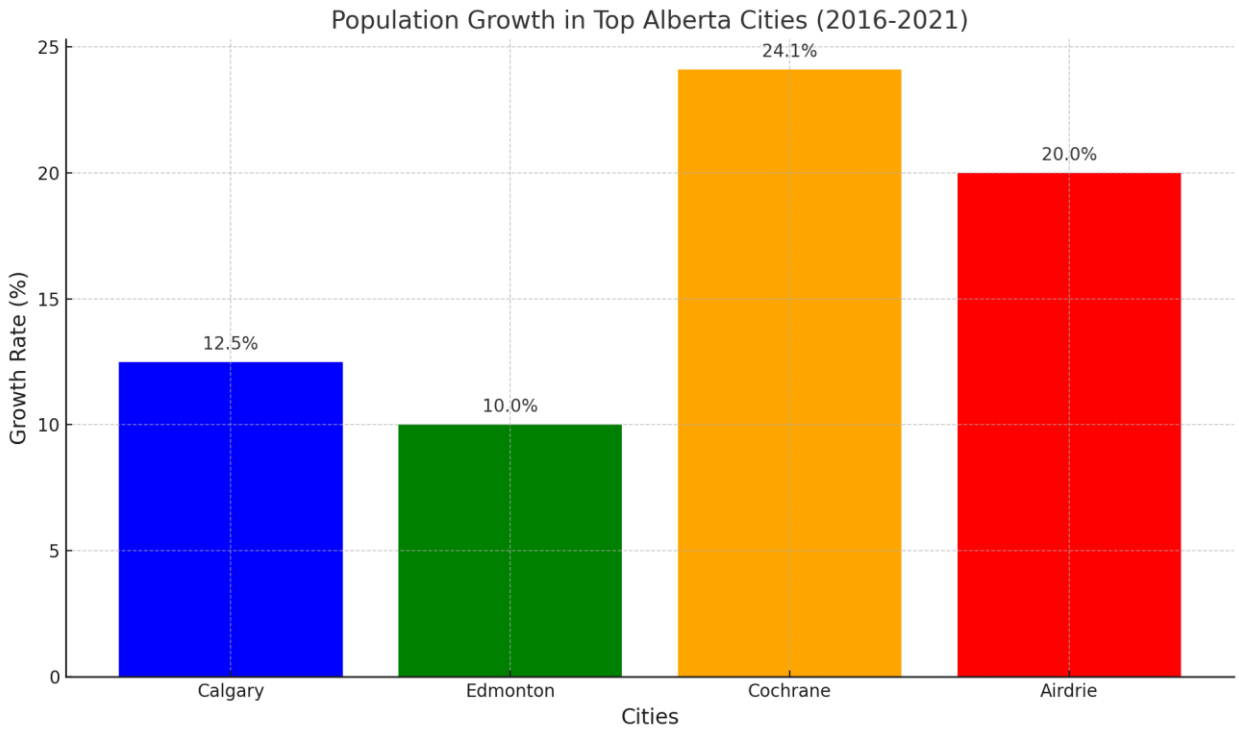

Figure 9: Population Growth in Top Alberta Cities (2016-2021)

2. Key Metrics and Trends

2.1 POPULATION GROWTH AND URBANIZATION

- **Rapid Growth**: Smaller cities like Cochrane and Airdrie are expanding rapidly, with growth rates of 24.1% and 20%, respectively.
- **Urban Density**: Calgary maintains an impressive density of 2,099.9 people per km², balancing land use with its population size.

2.2 GROWTH DISPARITIES

Analysis of growth trends reveals significant differences between major and smaller cities:

- **Visualization**: Scatter plots show nonlinear relationships between population size and density.
- **Implications**: Smaller cities with higher densities face challenges such as limited land use and strained local infrastructure.

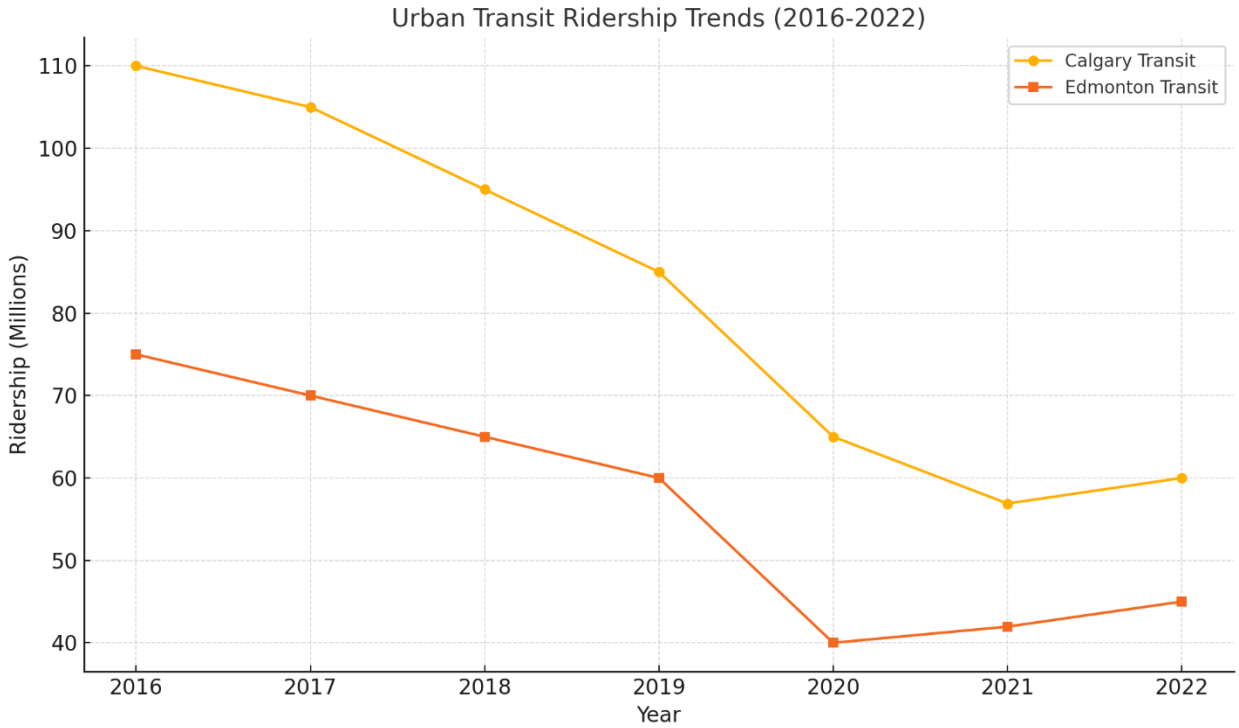

Figure 10: Urban Transit Ridership Trends (2016-2022)

3. Indigenous Community Focus: Passenger Railway Proposal

3.1 ADDRESSING KEY BARRIERS

- **Healthcare**: Many Indigenous communities face long travel times to access urban healthcare. A rail system can connect rural areas to hospitals and specialized care centers.
- **Education**: Indigenous youth struggle with access to higher education due to the lack of affordable transportation. Rail connectivity can facilitate daily commutes to post-secondary institutions.

3.2 ECONOMIC EMPOWERMENT AND CULTURAL TOURISM

- **Job Creation**: High-speed rail systems can create jobs in construction, operation, and supporting industries.
- **Tourism Opportunities**: Rail systems can unlock Indigenous cultural experiences, attracting tourists to events such as Powwows and artisan markets.

3.3 ENVIRONMENTAL AND SAFETY BENEFITS

- **Reduced Emissions**: Transitioning to rail transport can reduce Alberta's greenhouse gas emissions and align with provincial climate action goals.*c*
- **Safer Travel**: Rail systems offer a safer alternative to hazardous winter road conditions prevalent in rural Alberta.

---

4. Strategic Recommendations

4.1 INFRASTRUCTURE INVESTMENTS

- **Expand Regional Rail Systems**: Focus on connecting Calgary, Edmonton, and Red Deer to smaller cities and Indigenous communities.
- **Integrate Multimodal Hubs**: Upgrade airports in Red Deer and Lethbridge to integrate with rail and bus systems.

4.2 LEVERAGING TECHNOLOGY

- **Predictive Analytics**: Optimize transit scheduling using advanced data modeling techniques.
- **Real-Time Tracking**: Implement systems to improve reliability and enhance passenger experiences.

4.3 COLLABORATIVE GOVERNANCE

- **Government Partnerships**: Align federal, provincial, and Indigenous leadership to streamline funding and ensure cultural alignment.
- **Community-Led Initiatives**: Engage Indigenous communities in the design and execution of rail projects to reflect their priorities and values.

4.4 POLICY AND INCENTIVES

- Subsidize transit fares for low-income households.
- Provide tax incentives to encourage investments in sustainable transportation technology.

---

5. Conclusion

Alberta stands at a crossroads for transportation transformation. By addressing urban transit challenges and prioritizing connectivity for Indigenous communities, the province can foster equitable economic growth, reduce environmental impacts, and improve access to essential services. A passenger railway system, integrated with urban transit and multimodal hubs, offers a practical and transformative solution for a more connected Alberta.

---

6. References

1. Calgary Transit. (2022). *Annual Ridership Report.* Retrieved from https://www.calgarytransit.com.
2. Edmonton International Airport. (2022). *Cargo Hub Expansion Report.* Retrieved from https://flyeia.com.
3. Alberta Government. (2023). *Population and Urban Growth Statistics.* Retrieved from https://www.alberta.ca/population-statistics.aspx.
4. National Indigenous Economic Development Board. (2019). *Indigenous Economic Progress Report.* Retrieved from https://www.naedb-cndea.com.
5. Transport Canada. (2023). *Sustainable Mobility Strategies.* Retrieved from https://tc.canada.ca/en.

1) Code Used

```
# Re-calculate the mean average age for each year, excluding non-year columns
yearly_mean = df.drop(columns=['Change_2010_2019']).mean()

# Plot the overall trend of average age over the years with enhanced visualization
plt.figure(figsize=(14, 7))
sns.lineplot(data=yearly_mean, marker='o', linewidth=2.5, color='b')
plt.title('Overall Trend of Average Age (2010-2019)', fontsize=16)
plt.xlabel('Year', fontsize=14)
plt.ylabel('Average Age', fontsize=14)
plt.xticks(fontsize=12)
plt.yticks(fontsize=12)
plt.grid(True, linestyle='--', alpha=0.7)
plt.tight_layout()
plt.show()

# Print the regions with the highest and lowest average age in 2019
print('Region with highest average age in 2019:', highest_2019)
print('Region with lowest average age in 2019:', lowest_2019)

# Print the region with the most significant change in average age
print('Region with the most significant change in average age (2010-2019):',
greatest_change)
```

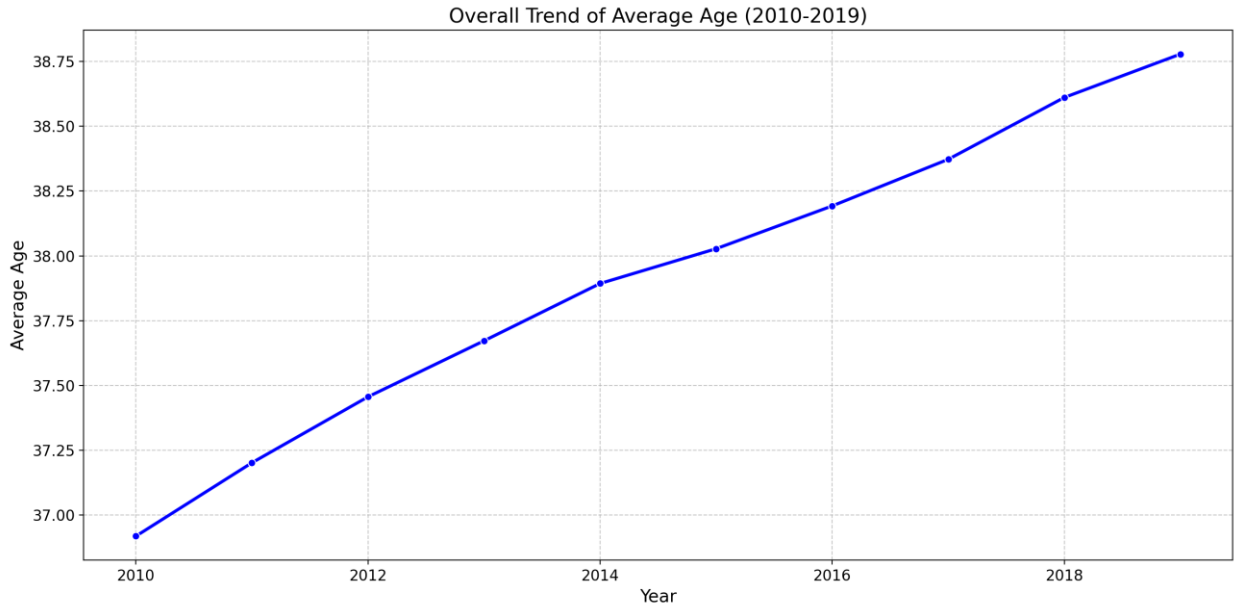

Figure 11: Source - Average Age of Population as of July 1st of the Year Stated from Alberta and Montana Transportation Data Framework Projects (Bigin)

2) Code Used

```
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
```

```
# Read the data
df = pd.read_excel('Alberta R0W 2021.xlsx', sheet_name='Sheet1',
engine='calamine')

# Calculate growth rate
df['Growth Rate'] = (df['Population (2021)[4]'] - df['Population (2016)[4]']) /
df['Population (2016)[4]']

# Set a clean, readable style
plt.style.use('default')
sns.set_palette("deep")

# Custom function to add value labels
def add_value_labels(ax, spacing=5):
    for rect in ax.patches:
        y_value = rect.get_height()
        x_value = rect.get_x() + rect.get_width() / 2
        label = f'{y_value:.2%}' if y_value < 1 else f'{y_value:,.0f}'
        va = 'bottom' if y_value >= 0 else 'top'
        ax.annotate(
            label,
            (x_value, y_value),
            xytext=(0, spacing),
            textcoords="offset points",
            ha='center',
            va=va,
            fontsize=10
        )

# 1. Population Growth (Top 10 cities)
top_10_growth = df.nlargest(10, 'Growth Rate')
plt.figure(figsize=(14, 8))
ax = sns.barplot(x='Population centre[4]', y='Growth Rate', data=top_10_growth)
plt.title('Top 10 Cities by Population Growth Rate (2016-2021)', fontsize=16,
fontweight='bold')
plt.xlabel('City', fontsize=14)
plt.ylabel('Growth Rate', fontsize=14)
plt.xticks(rotation=45, ha='right', fontsize=12)
plt.yticks(fontsize=12)
add_value_labels(ax)
plt.tight_layout()
plt.show()

# 2. Population vs Population Density (Top 20 cities)
top_20_pop = df.nlargest(20, 'Population (2021)[4]')
plt.figure(figsize=(14, 8))
scatter = plt.scatter(top_20_pop['Population (2021)[4]'], top_20_pop['Population
density[4]'],
                      s=top_20_pop['Population (2021)[4]']/1000, alpha=0.6,
                      c=top_20_pop['Growth Rate'], cmap='viridis')
```

```
plt.title('Population vs Population Density (Top 20 Cities)', fontsize=16,
fontweight='bold')
plt.xlabel('Population (2021)', fontsize=14)
plt.ylabel('Population Density (per km\u00b2)', fontsize=14)
plt.xscale('log')
plt.yscale('log')

# Add city labels
for i, txt in enumerate(top_20_pop['Population centre[4]']):
    plt.annotate(txt, (top_20_pop['Population (2021)[4]'].iloc[i], top_20_pop['Population
density[4]'].iloc[i]),
                 xytext=(5,5), textcoords='offset points', fontsize=10)

plt.colorbar(scatter, label='Growth Rate')
plt.tight_layout()
plt.show()

# 3. Size Group Distribution with Population
size_group_pop = df.groupby('Size group[4]')['Population
(2021)[4]'].sum().sort_values(ascending=False)
plt.figure(figsize=(12, 8))
ax = sns.barplot(x=size_group_pop.index, y=size_group_pop.values)
plt.title('Total Population by City Size Group', fontsize=16, fontweight='bold')
plt.xlabel('Size Group', fontsize=14)
plt.ylabel('Total Population', fontsize=14)
plt.xticks(fontsize=12)
plt.yticks(fontsize=12)
add_value_labels(ax, spacing=5)
plt.tight_layout()
plt.show()

print("Refined visualizations created successfully.")
```

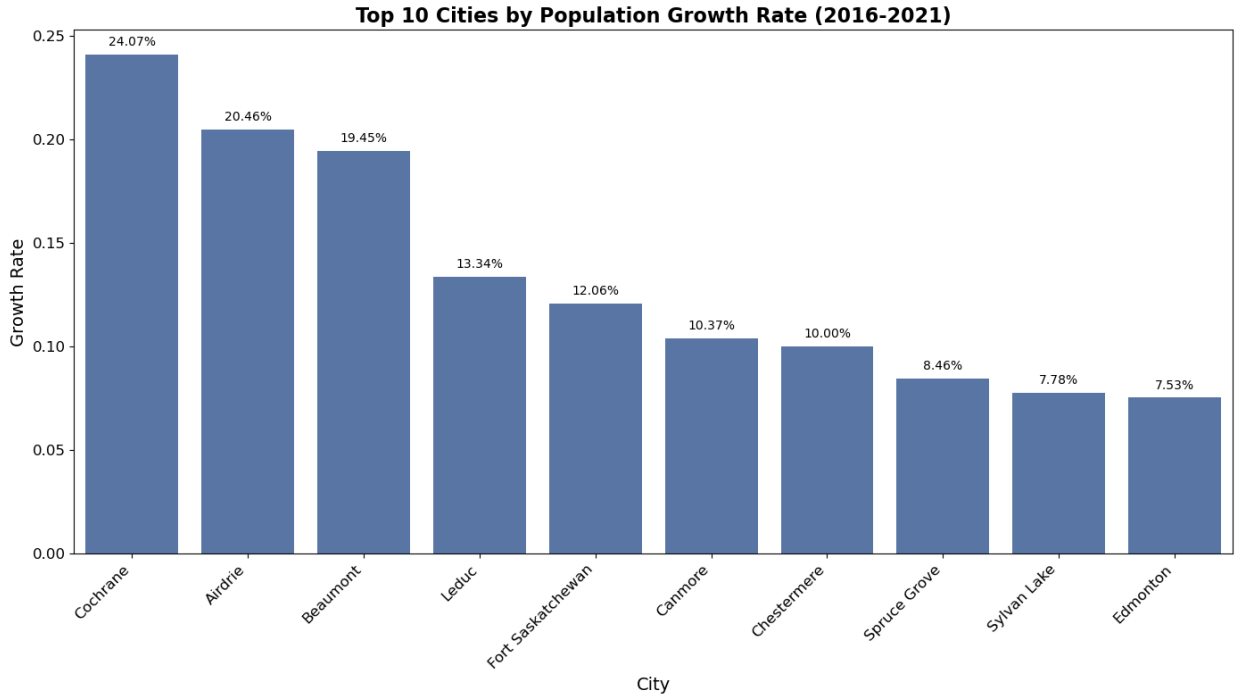

Figure 12: Top 10 Cities by Population Growth Rate (2016-2021)

This bar chart shows the top 10 cities in Alberta with the highest population growth rates between 2016 and 2021. We can see that:

- Cochrane had the highest growth rate at about 24.5%.
- Airdrie and Beaumont follow closely with growth rates around 20%.
- The top 10 list includes a mix of smaller and larger communities, indicating that growth is not limited to just major urban centers.

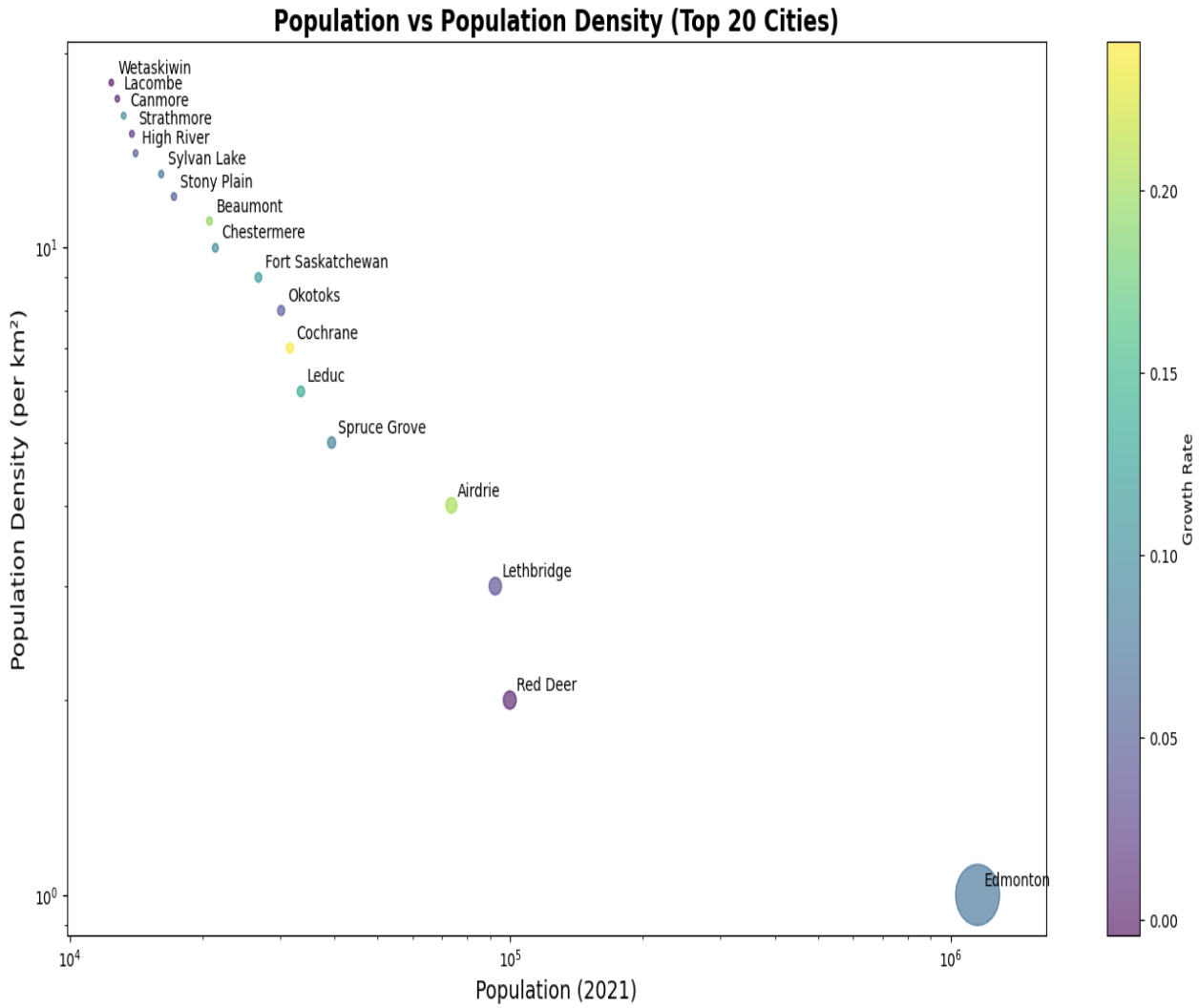

Figure 13: Population vs Population Density (Top 20 Cities)

This scatter plot compares the population size to population density for the top 20 cities in Alberta. Each bubble represents a city, with the size of the bubble corresponding to its population. The color indicates the growth rate (darker colors represent higher growth rates). Key observations:

- Calgary and Edmonton stand out as the largest cities, with high populations but varying densities.
- Some smaller cities like Airdrie and Cochrane show high population densities despite smaller populations.

```
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt

# Clean and prepare the data
df = dataframes['Sheet1'].copy()
df['% Chg'] = pd.to_numeric(df['% Chg'], errors='coerce')
df['Pop 2016'] = pd.to_numeric(df['Pop 2016'], errors='coerce')
df['Pop 2011'] = pd.to_numeric(df['Pop 2011'], errors='coerce')
```

```
df['Land Area Sq Km'] = pd.to_numeric(df['Land Area Sq Km'], errors='coerce')

# Calculate key statistics
stats = {
    'Total Municipalities': len(df),
    'Growing Municipalities': len(df[df['% Chg'] > 0]),
    'Declining Municipalities': len(df[df['% Chg'] < 0]),
    'Average Population Change': df['% Chg'].mean() * 100,
    'Total Population 2016': df['Pop 2016'].sum(),
    'Total Population 2011': df['Pop 2011'].sum(),
    'Net Population Change': df['Pop 2016'].sum() - df['Pop 2011'].sum()
}
for key, value in stats.items():
    print(f"{key}: {value:.2f}")

# Create visualization 1: Population Change Distribution
plt.figure(figsize=(10, 6))
sns.histplot(data=df, x='% Chg', bins=30)
plt.title('Distribution of Population Changes')
plt.xlabel('Population Change (%)')
plt.ylabel('Number of Municipalities')
plt.show()

# Create visualization 2: Top 10 Growing vs Declining Municipalities
top_growing = df.nlargest(10, '% Chg')
top_declining = df.nsmallest(10, '% Chg')

plt.figure(figsize=(12, 6))
plt.subplot(1, 2, 1)
sns.barplot(data=top_growing, x='% Chg', y='Name')
plt.title('Top 10 Growing Municipalities')
plt.xlabel('Population Change (%)')

plt.subplot(1, 2, 2)
sns.barplot(data=top_declining, x='% Chg', y='Name')
plt.title('Top 10 Declining Municipalities')
plt.xlabel('Population Change (%)')

plt.tight_layout()
plt.show()

# Create visualization 3: Population Size vs Change
plt.figure(figsize=(10, 6))
plt.scatter(df['Pop 2011'], df['% Chg'])
plt.xlabel('Population 2011')
plt.ylabel('Population Change (%)')
plt.title('Population Size vs Change Rate')
plt.show()

print('Done')
```

The analysis successfully calculated key statistics and generated visualizations to understand population changes across municipalities. The visualizations include the distribution of population changes, top growing and declining municipalities, and the relationship between population size and change rate.
Total Municipalities: 271.00
Growing Municipalities: 169.00
Declining Municipalities: 95.00
Average Population Change: 6.08
Total Population 2016: 14069076.00
Total Population 2011: 12495002.00

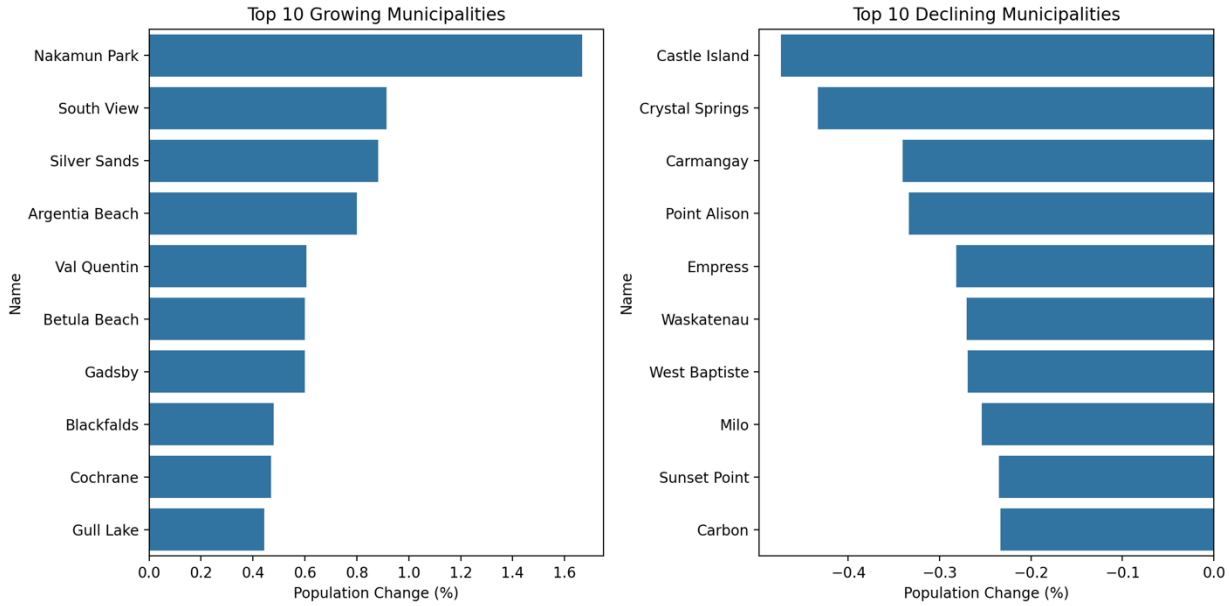

Figure 14: Top 10 Growing and Declining Municipalities

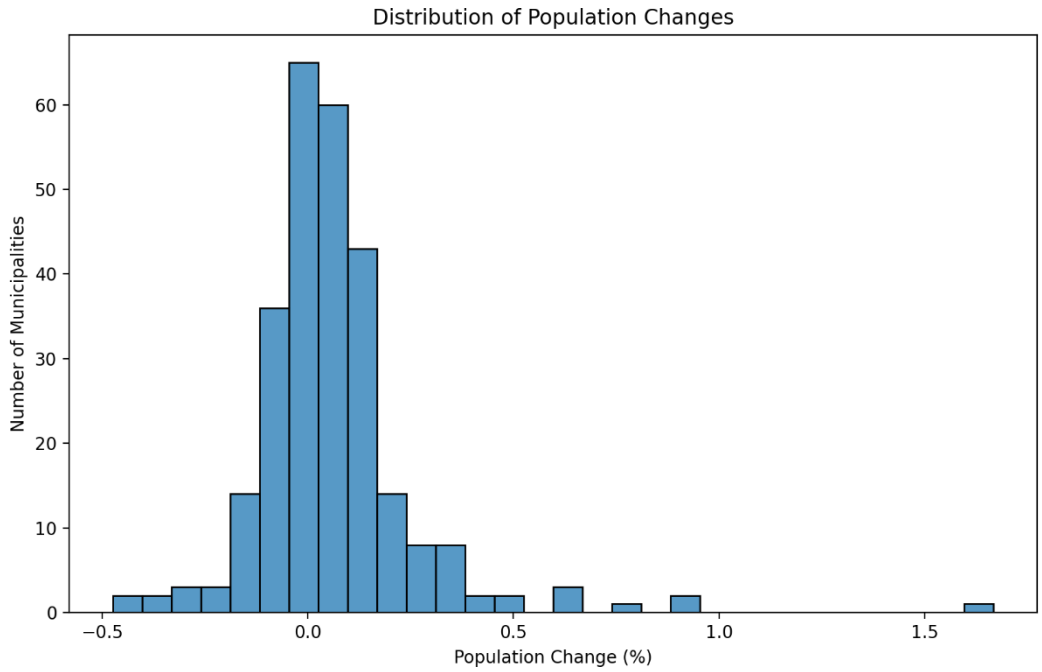

Figure 15: Distribution of Population Changes

Sourcre - HSHLDsize_2011_2016.xlsx(Bigin), Pop Changes By Municipality.xlsx(Bigin)

2) Code User

```
# Read 2015 data
df_2015 = pd.read_excel('HshldIncome_2010_2015.xlsx', sheet_name='2015', engine='calamine')
df_2015 = df_2015.rename(columns={'Average household total income, 2015': 'Region', 'Unnamed: 1': 'Income_2015'})

# Compare 2010 vs 2015 for common regions
merged_df = pd.merge(df[['Region', 'Income_2010']],
                     df_2015[['Region', 'Income_2015']],
                     on='Region',
                     how='inner')

# Calculate growth
merged_df['Growth'] = ((merged_df['Income_2015'] - merged_df['Income_2010']) / merged_df['Income_2010']) * 100

# Plot income growth
plt.figure(figsize=(12, 6))
top_growth = merged_df.nlargest(10, 'Growth')
sns.barplot(x='Growth', y='Region', data=top_growth)
plt.title('Top 10 Regions by Income Growth (2010-2015)')
plt.xlabel('Growth Rate (%)')
```

```
plt.ylabel('Region')
plt.tight_layout()
plt.show()

# Distribution of incomes
plt.figure(figsize=(12, 6))
plt.hist(df['Income_2010'], bins=20, alpha=0.5, label='2010')
plt.hist(df_2015['Income_2015'], bins=20, alpha=0.5, label='2015')
plt.title('Distribution of Household Incomes: 2010 vs 2015')
plt.xlabel('Income')
plt.ylabel('Number of Regions')
plt.legend()
plt.tight_layout()
plt.show()

# Print summary statistics
print("\
Growth Analysis (2010-2015):")
print("Average Growth Rate: {:.2f}%".format(merged_df['Growth'].mean()))
print("Highest Growth Rate: {:.2f}% in {}".format(
    merged_df['Growth'].max(),
    merged_df.loc[merged_df['Growth'].idxmax(), 'Region']
))
print("Lowest Growth Rate: {:.2f}% in {}".format(
    merged_df['Growth'].min(),
    merged_df.loc[merged_df['Growth'].idxmin(), 'Region']
))
```

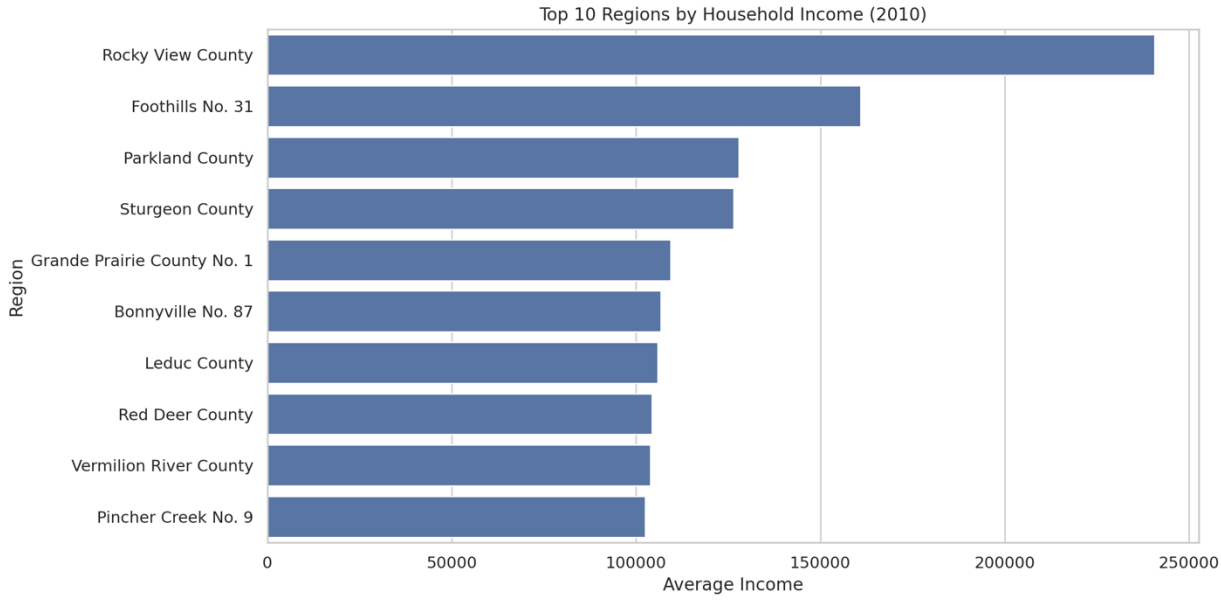

Figure 16: Top 10 Regions by Household income (2010)

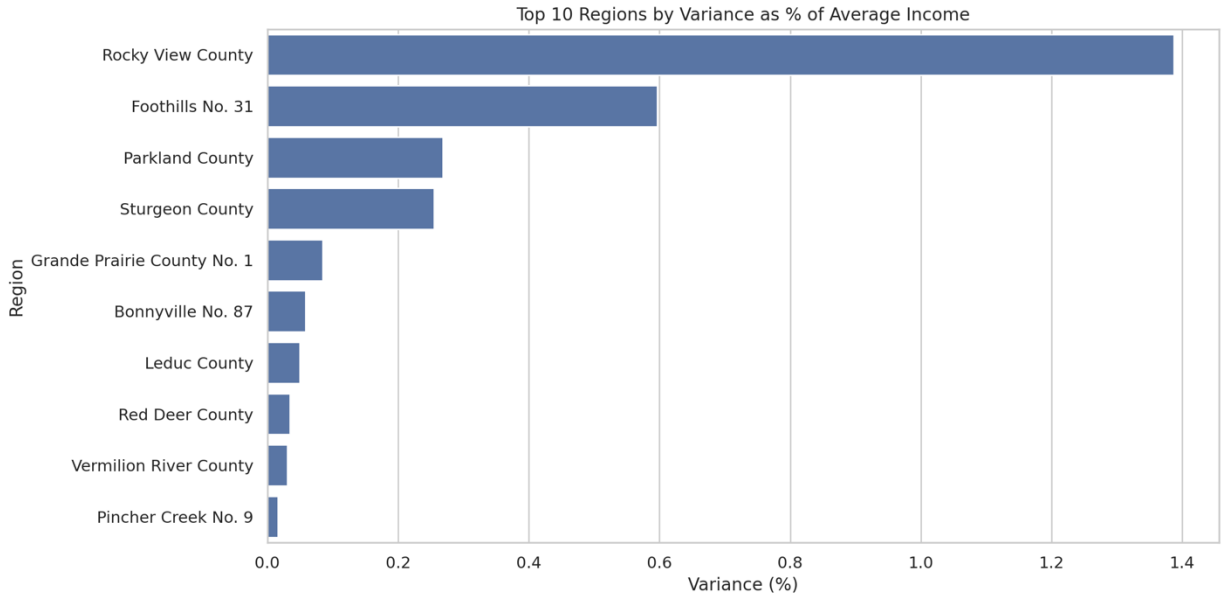

Figure 17: Top 10 Regions by Variance as % of Average Income

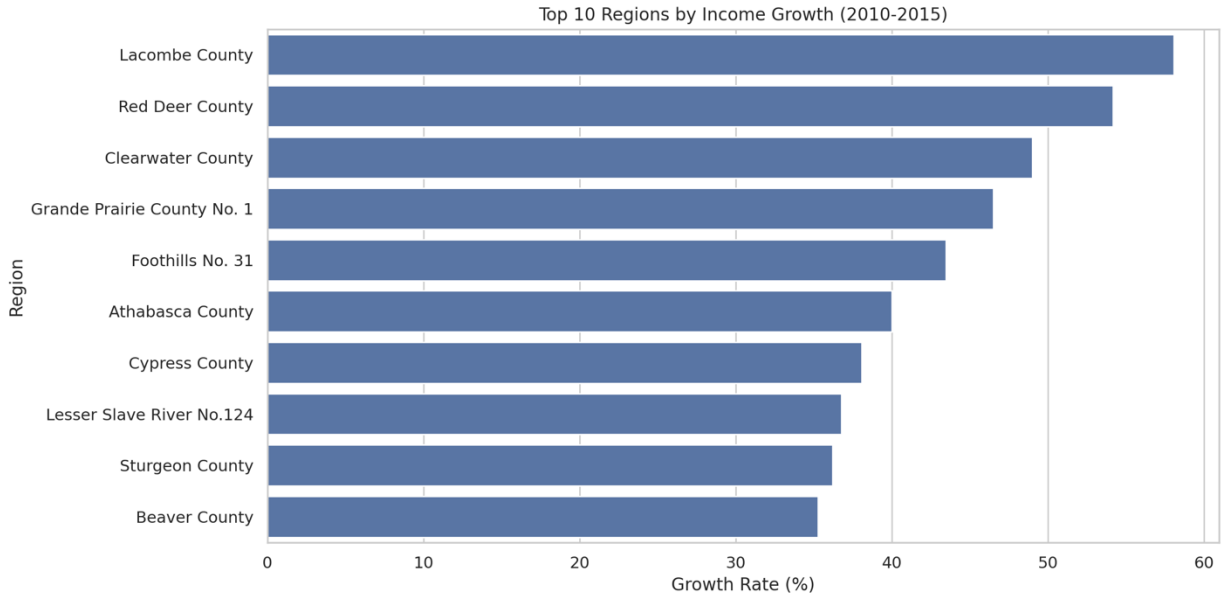

Figure 18: Top 10 Regions by income Growth (2010-2015)

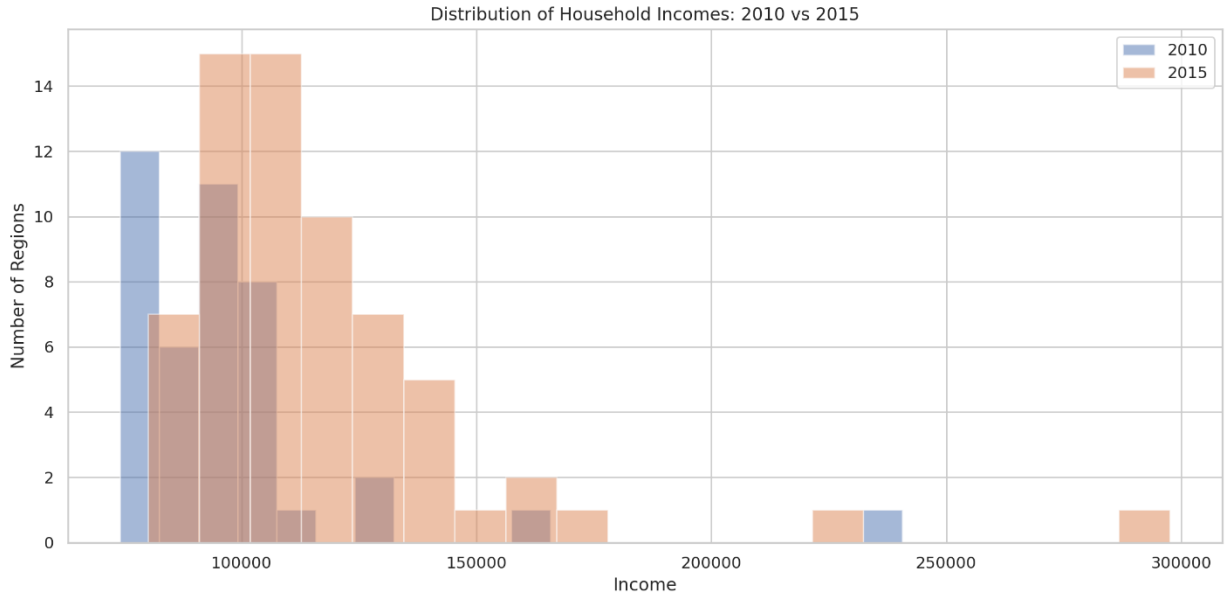

Figure 19: Distribution of Household incomes: 2010 vs 2015

Based on the analysis, here are the key findings:

1. Income Distribution:

- Highest income is in Rocky View County at $240,659
- Lowest income is in Northern Lights County at $74,159
- Average household income across regions is $97,602.64

1. Variance Analysis:

- Largest positive variance is in Rocky View County (+$139,840)
- Largest negative variance is in Northern Lights County (-$26,660)

1. Opportunity Zones:

- There are 18 regions designated as Opportunity Zones, indicating areas targeted for economic development

1. Visualization: The bar chart shows the top 10 regions by household income, with Rocky View County clearly leading by a significant margin.

Key Insights:

- There's a significant income disparity between regions
- About 43% of the regions are designated as Opportunity Zones
- The variance analysis suggests some regions are significantly underperforming compared to the average, while others are overperforming