Funding Transportation Projects via the Investing in Canada Plan – An Empirical Analysis on the Implementation through a Balanced Regional Development Perspective

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1. Introduction

Stewards of infrastructure facilities in western countries are making massive investments to renew their infrastructure systems, as a result of many of their facilities – which are built during the post WWII economic expansion – are approaching their end of life. These investment plans frequently value billion (or trillion) dollars and may shape the built environment we live in for coming decades. Facilitating regional development is one of the core functions of infrastructure, and this study specifically focuses on the performance of investment plan on fulfilling the specific mission across regions during the implementation. Compared to other policy processes (i.e., agenda setting, forming, decision-making, and evaluation), implementation receives less attention among either researchers or the public. Sometimes referred as "agency development", the implementation of investment plan has passed the legislature and not yet generates tangible outcomes. Examples in the context include the generation of funding programs with detailed budget plans, as well as the planning, awarding, and delivery of infrastructure projects. A timely empirical analysis on the implementation can not only provide ongoing investment plans opportunities for enhancement and effort redirections, also furnish later plans evidence-based insights.

The Investing in Canada Plan is a comprehensive infrastructure investment initiative launched by the Government of Canada in 2016, with a commitment of over $180 billion over 12 years. Aiming at achieving objectives on the aspects of job & growth, sustainable & resilient, and inclusive & accessible, the plan covers a wide range of infrastructure sectors, including transportation. As of mid-2023, around 80% of the budget has committed, which enable sufficient data for analysis. The Canadian plan is ahead of infrastructure investment plans alike in other counties (e.g., the Infrastructure Investment and Job Act in the United States, the Infrastructure Investment Program of Australia, and the National Infrastructure Delivery Plan and Pipeline of the United Kingdom) in terms of policy process. Therefore, the empirical analysis in this study can generate benefits beyond border – helping refocusing the Canadian plan before it closes while offering insights to the delivery of non-Canadian projects.

2. Literature Review

Balanced transportation investment among regions, or in a more general and prevalent term – transportation equity, is getting increasing attentions among researchers over the past three decades. In 1990s, as the public's social awareness increased, discussions on disadvantaged communities's mobility and connectivity emerged (Mercier, 2009). Studies are conducted to explore the relationships between transportation mobility and connectivity and served communities' attributes on gender, ethnicity, age, class, and disability (Church et al., 2000). Frameworks, amendments, and assessment are generated to help include equity considerations into decision-makings on transportation planning, including funding distributing (Martens and Golub, 2012; Golub and Martens, 2014; Manaugh et al., 2014; Hananel and Berechman, 2016; Adli and Donovan, 2018). However, these works are more about theoretical discussion and fall outside the field of empirical studies.

Empirically, Foth et al. (2013) investigated the distribution of public transits in Toronto and found that the transit system generally benefits socially disadvantaged groups, providing better accessibility and lower travel times in areas with higher social disadvantages. On contrary, Ryan et al. (2021) found that municipal highway funding in the United States disproportionately favors wealthier regions, resulting in safety disparities and emphasizing the importance of considering social differences in funding mechanism. Investments examined in existing empirical studies are almost exclusively projects on regular budgets. Compared to infrastructure investment plans being executed across countries, these regular (or annual) investments are across longer periods of time, smaller in each installment, and made under varied settings. To the best of the authors' knowledge, there is no prior study examining investment plans as discussed in the first paragraph, including the Investing in Canada Plan. The significance of this study are twofolds. First, it is necessary to examine the actual performance of infrastructure investment plan on facilitating balanced regional development. These plans are designed in a setting where decisions are made by a relatively smaller and more assembled group of people over a short period of time with equity as a priority. Second, dedicated empirical studies on these investment plans are crucial because of the plans' potential, profound impacts and limited chances for amendments.

3. Research Hypotheses, Data, and Methodology

This study has three hypotheses:

H1 (gearing towards areas with less constructed facilities): Transportation facilities per person is negatively correlated to investment per capita.

H2 (gearing towards areas with concentrated economically disadvantaged people): Economic conditions are negatively correlated to investment per capita.

H3 (gearing towards areas with concentrated socially disadvantaged people): Proportions of ethnic minority, language minority, and new immigrants are negatively correlated to investment per capita.

To support hypothesis testings, below 23 variables are collected. The variables are consisted of 1 dependent variable (i.e., investment amount) and 22 explanatory variables which can be classified into three categories: transportation assets (incl. miles of paved/unpaved roads, number of vehicles, average distance drive, freight activities, and airport passenger traffic), economic indexes (incl. unemployment rate, poverty rate, medium household income, GDP per capita, inflation), and demographic attributes (incl. population, population density, gender, age distribution, ethnicity, language spoken, proportion of new immigrants, homelessness rate, and disability rate). Almost all date except airport passengers can be found at the websites of Government of Canada or Statistics Canada. For time series variables (e.g., population), data within the range of 2014-2018 (a five-year window centering 2016) will be collected. When an attribute's data are not available within the range, cross-sectional data closest to 2016 will be adopted. The rationales lie in (1) different variables' survey cycles vary and may not be available annually; and (2) decisions on funding allocation are made over a period of time centering around 2016.

Considering needs on data visualization, ArcGIS 10.8 will be applied as the computing software. Both Ordinary Least Square (OLS) and Geographically Weighted Regression (GWR) methods were applied on the data set. Normally, OLS can provide a robust-enough, first-order, universal model. By introducing second-order, local variations, GWR has the capability to accommodate non-stationary (i.e., time series) variables. By analyzing the spatial dependencies of non-stationary variables, GWR can process information on spatial heterogeneity. Nevertheless, GWR models can cause overfitting if involved non-stationary variables do not have strong non-stationarity. Therefore, both OLS and GWR will be applied. Model diagnosis will be conducted to compare their individual performance (e.g., adjusted R-square, AIC, BIC). Variance inflation factor (VIF) will be calculated before variables bringing into models for variable selection purposes.

4. Feasibility analysis

This study is still undergoing, and the authors have a solid plan to make it ready by EPOC conference. To demonstrate that the data and the methodology suffice the needs on intended hypothesis testing, a pilot study is introduced as below. It was performed by a student co-supervised by the authors. The first author contributed the conceptualization and the study design, and the student did the data analysis. On top of the results of pilot study, the two authors plan to redo the whole work by enhancing literature review, improving study design, updating hypothesis design, re-conducting data collection, and conducting data analysis.

"*ArcMap 10.4 was employed to conduct the GWR analysis. The adaptive kernel method was utilized for geographical weighting, allowing for the estimation of local coefficients and bandwidth size. The software also offers OLS modeling results, which are useful for comparing GWR and OLS results. The OLS technique is used to estimate parameters in linear regression models.*

In this study, two primary components are presented: the selection of variables and the spatial analysis. First, a literature review was conducted to identify candidate variables. Second, in order to find the suitable variables, an exploratory regression analysis was performed. Finally, in order to examine the spatial analysis of the amount of investment in a certain area and demographic attributes of Canadian society, both GWR and OLS methods were used.It is important to select appropriate and applicable variables in order to assess how investment impacts the Canadian society from a social justice perspective. A review of related research models was performed by the author, focusing on social justice in transportation planning. As a result of this literature review, the author identified 11 potential variables (Table 1), which were further refined (see the following sections).

TABLE 1. The dependent and independent variables.

Dependent Variable	***Description of Measure***	***Data Sources***
Investment per capita	*Investments Per Province*	*Government of Canada Website*
Independent Variables	***Description of Measure***	*Statistics Canada Website*
*Population**	-	*Statistics Canada Website*
*Population Density**	*Population Per Area*	*Statistics Canada Website*
*GDP Per Capita**	*GDP Per Population*	*Statistics Canada Website*
Miles of Road Per Person	*Total Length of Roads Per Population*	*Statistics Canada Website*
*Age Group (0 to14)**	-	*Statistics Canada Website*
*Age Group (15 to 64)**	-	*Statistics Canada Website*
*Age Group (65 and above)**	-	*Statistics Canada Website*
*Female Population**	-	*Statistics Canada Website*
*Male Population**	-	*Statistics Canada Website*
Unemployment Rate	-	*Statistics Canada Website*
*Employment Rate**	-	*Statistics Canada Website*

** Due to multicollinearity, this variable was removed*

It can be difficult to find a properly specified GWR and OLS model, especially when there are many potential independent variables that may contribute to the dependent variable. Therefore, in this study, exploratory regression was used in order to increase the chances of finding the right model by considering all possible combinations of candidate independent variables (Esri, n.d.).

The exploratory regression was tested through the implementation by ArcMap 10.4, which determined that two out of 11 variables had a significant correlation with the amount of investment: unemployment rate and miles of road per person, which had a p-value less than 0.05. The chosen variables were inspected for multicollinearity, utilizing the variance inflation factor (VIF) as a metric for assessment. Generally, a VIF score below 7.5 indicates no significant multicollinearity, which means it won't substantially impact the stability of parameter estimates. In this case, the VIF scores for the two variables were 1.230684, suggesting no multicollinearity, and therefore, these variables were deemed suitable for the regression model.

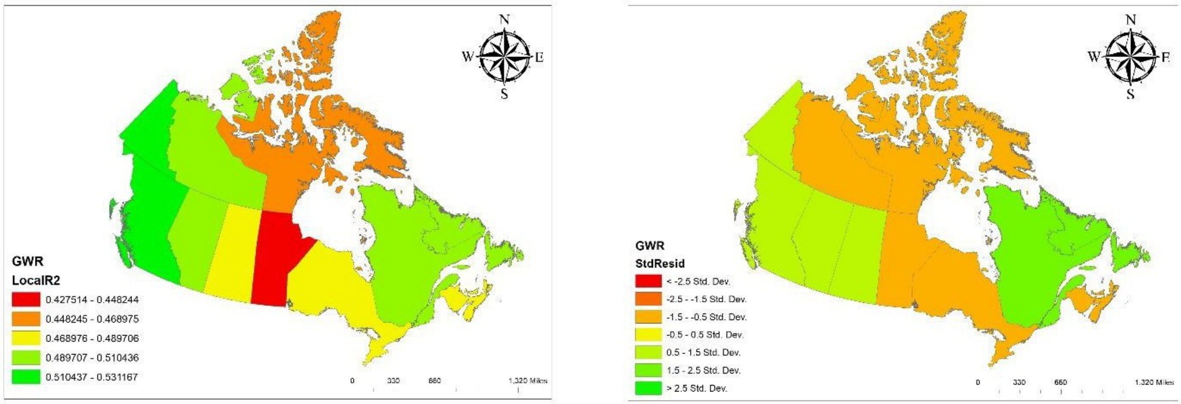
Data for the case study was obtained from public sources, and variables required for regression analysis were gathered from Statistics Canada websites. The miles of road per person and population density variables were computed using ArcMap version 10.4. To prevent errors due to differing unit sizes among *variables, all data was standardized before conducting regression analysis. This study employed the PCS Lambert Conformal Conic coordinate system for the GIS projection within ArcMap software.*

According to the GWR and OLS analyses, there is a negative correlation between the amount of investment in provinces and two variables: miles of road per person and unemployment rate. The evaluation of the GWR model's performance can be conducted through an analysis of the estimated local R2 values and standard residuals. The distribution of local R2 values is illustrated in Figure 1a, with values ranging from 0 to 1. Higher values indicate better local model performance, while lower values suggest inadequate model performance for a given region. For instance, British Columbia exhibits the highest LocalR2 at 0.52856511, implying that the GWR model is more suited to this region compared to others. Figure 1b displays the distribution of standard deviations of residuals, which indicates that the assessment model is unsuccessful in explaining the relationship if the value is below -2.5 or above 2.5. No districts exhibited standard residuals greater than 2.5 or less than -2.5; therefore, the assessment model can explain the relationship between investment and unemployment rates and miles of road per person in all regions.

The model-related parameters of the two analyses are shown in Table 2. Based on OLS regression results, the model shows that both miles of road per person and unemployment rate have a significant negative relationship with investment. The model has a Multiple R-Squared value of 0.501015 and an Adjusted R- Squared value of 0.401218, indicating that approximately 40% of the variation in investment can be explained by the model.

The GWR report shows that the adjusted R-squared value is 0.235107, which is lower than the OLS model. This suggests that the GWR model might not be the most appropriate method for this analysis. However, the AICc value of 245.58 indicates that the GWR model is still a reasonable fit. Considering all three factors, it seems that the OLS model has a better overall fit for analysis, as it has a higher Adjusted R2 and a significantly lower AICc value compared to the GWR model.

From a social justice perspective, the negative relationship between miles of road per person and unemployment rate with investment suggests that areas with higher unemployment rates and more miles of road per person receive less investment. This may indicate that the distribution of infrastructure investment is not equitable across different regions, potentially exacerbating existing inequalities. Additional research should be conducted to further investigate the social justice implications of the Investing in Canada Plan's transportation projects and more attributes could be added and tested using the model if the relevant data are available."



(a) (b)

Figure 1. (a) local R2 spatial distribution and (b) standard residual spatial distribution.

TABLE 2. Comparison of model test results.

Model	*R2*	*Adj. R2*	*AICc*
GWR	*0.555487*	*0.235107*	*245.580541*
OLS	*0.501015*	*0.401218*	*39.814513*