ICCEPM 2022
The 9th International Conference on Construction Engineering and Project Management
Jun. 20-23, 2022, Las Vegas, NV, USA

Impact of Bridge Construction on County Population in Georgia

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Abstract: Past research shows that the construction of new infrastructure accelerates economic growth in the region by attracting more people and commodities. However, the previous studies only considered large-scale infrastructures such as sea-cross bridges and channel tunnels. There is a paucity of literature on regional infrastructure and its impact on socio-economic indicators. This paper explores the impact of new bridge construction on the human population, particularly focusing on regional bridges constructed during the 2000s in the state of Georgia. The human population at a county level was selected as a single socio-economic factor to be evaluated. A total of 124 cases were investigated as to whether the emergence of a new bridge affected the population change. The interrupted time series analysis was used to statistically examine the significance of population change due to the construction by treating each new bridge as an intervention event. The results show that, out of the 124 cases, the population of 67 cases significantly increased after the bridge construction, while the population of 57 cases was not affected by the construction at a significance level of 0.05. The 124 cases were also analyzed by route type, functional class, and traffic volume, but the results revealed, unlike large-scale infrastructure, that no clear evidence was found that a new bridge would bring an increase in the human population at a county level.

Key words: bridge construction, human population, socio-economic indicator, interrupted time series analysis

1. INTRODUCTION

It is inarguable that developed countries have a more flourished infrastructure system than developing countries do, as it has been observed that the construction of new infrastructure tends to promote economic growth and development in a society. Among various infrastructure systems, bridges play an important role and contribute to economic development by connecting an isolated area (e.g., an island or a rural region) to a developed city. This connection via a bridge enables materials and labor to fast move to the isolated regions, leading to rapid economic development.

Past research shows how a new bridge construction positively affects a connected area socially and economically. Chu et al. conducted a case study on how the Hangzhou Bay bridge construction influences land use and socio-economic factors [1]. The study found that, after connecting two cities with the bay bridge, the land use in both cities showed a rapid expansion, and other socio-economic indicators such as gross domestic product (GDP), tourism, and freight also significantly increased. A similar study was conducted for a set of newly constructed sea-cross bridges that connected the mainland of China to nearby islands [2]. The authors concluded the new infrastructure brought a prompt increase in land use followed by urbanization accelerated by economic growth. Another example that exhibits the role of new bridge construction on economic development was presented in a study in Indonesia in which economic factors such as population, unemployment rate, investment, and land use were all dynamically changed after a bridge connected a smaller island to a big one [3].

It is worth noting that these studies all focused on a large-scale bridge connecting a large city or mainland to an island. However, there is a lack of study that incorporates small to medium size bridges that exist at a regional level. The present study was motivated by a question that tests the following null hypothesis: Construction of a new bridge within a county has *no* significant impact on the increase of county population. The main thrust of this research was to provide evidence that the null hypothesis is either accepted or rejected by analyzing bridges at a county level and the population change in their county. This paper particularly focused on regional (county-level) bridges constructed during the 2000s in the state of Georgia (GA) in the United States (US). The interrupted time series analysis (ITSA) was used as a tool to statistically examine the significance of population change due to the construction by treating each new bridge as an intervention event. The following section provides a research approach including a data collection and reduction scheme and a brief overview of the ITSA.

2. RESEARCH APPROACH

2.1. Data collection and reduction

The office of bridges and structures of the Federal Highway Administration (FHWA) regularly receives bridge inspection data from federal, state, and other local agencies to maintain the nation's bridges in accordance with the Code of Federal Regulations (23 CFR 650.3) [4]. The national bridge inventory (NBI) database managed by the office is accessible to the public and downloadable at the referenced webpage [5]. For the present study, we retrieved the most recent version of NBI of GA that contained a total of 14,964 bridges with their relevant data. The dataset furnishes a substantial amount of descriptive and numerical information about individual bridges including, but not limited to, geographical location, route type (e.g., interstate highway, US highway, state highway, etc.), functional classification (e.g., urban or rural, principal or minor arterial, etc.), level of service (e.g., mainline, alternate, bypass, ramp, etc.), year built, average daily traffic, and such.

With the bridge data gathered, we also collected human population data of every county in GA from the US census bureau [6], as the bureau is considered the provider of quality population data for the country. We focused on the county population change over the past 30 years and thus the county-level population data of GA from 1990 to 2019 were obtained.

The 14,964 bridges were then sorted out by their built year, only to include the bridges constructed in the 2000s. This is because an ITSA necessitates sufficient data *before* and *after* an intervention event: a new bridge construction. For example, if a bridge was constructed in the year 2001, the bridge would have adequate population data prior to its construction (i.e., from 1990 to 2000) as well as the data thereafter (i.e., from 2002 to 2019), in order to run an ITSA. This scheme supplies sufficient data for developing a robust time series regression model which is, in turn, able to be used to evaluate the model's coefficients and test the null hypothesis: whether the emergence of a bridge impacts the change of population in a particular county.

After applying the insular built-year constraint on the entire 14,964 bridges, the number of bridges available for analysis was reduced to 682. The 682 bridges were further sorted out to only consider any bridges above a county level including Interstate highways, US highways, State highways, and County highways. The final database also excluded any supplementary bridge structures such as ramps, spur bridges, and wye structures as well as bridges with less than 1,000 average daily traffic (ADT). After the data reduction, the number of bridges ended up with 239 bridges in 67 counties. It should be noted that the ITSA was conducted on the population change in 67 counties, but bridges could be built in different years in the same county. With all these cases (i.e., multiple bridges in one county) considered, the final number of cases for the ITSA was increased to 124.

2.2. Interrupted time series analysis

A time series is a collection of continuous outcomes that are observed over time. An interrupted time series (ITS) is a special type of time series that involves an event or an intervention that occurs at a specific point in time. The purpose of using an ITS is to evaluate whether an event has an impact on a given time series and thus leads to the significant change of a dependent variable before and after the event. The ITS was first proposed by Campbell [7] and since then the technique has been widely used in the social science and medical field to assess a treatment effect.

As mentioned earlier, the present study considered the completion of bridge construction as an event or intervention and attempted to see if there was a significant change in the human population before and after the bridge construction at a county level. In a standard ITSA, a simple regression model is set as follows:

$$Y_t = \beta_0 + \beta_1 T + \beta_2 X_t + \beta_3 T X_t \tag{1}$$

where Y_t is the dependent variable (e.g., the human population in this study) at a given time point; β_0, β_1, β_2, and β_3 are coefficients that respectively represent the baseline at a time (T) = 0, the change of outcome over time, the level change after an intervention (X_t), and the slope change following the intervention. The significance of the intervention term along with the slope change is evaluated and a p-value associated is calculated based on t-statistics.

Figure 1 illustrates a county population profile over 30 years as a typical time series with an intervention event (i.e., completion of bridge construction) depicted as a vertical dotted line in 2000. It visually appears that the population in Calhoun county, GA was substantially increased in 2000 and can be said to be affected by the bridge based on the calculated p-value ($p \leq 0.05$).

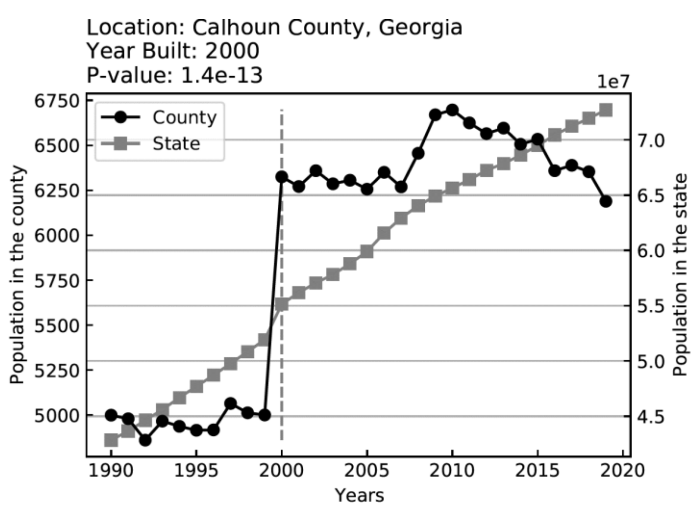

Figure 1. Population profile of Calhoun County, GA

It should be recognized that several different ITS patterns exist depending on whether the influenced outcome is temporary or permanent, and whether the onset of impact is gradual or abrupt [8]. These impact patterns are illustrated in Figure 2 and the population change of Calhoun county shown in Figure 1 seems to best fit with an abrupt and permanent pattern. It is a common technique that the best statistical model of a given interrupted time series dataset is based on the autoregressive integrated moving average (ARIMA) model [9]. For the ITSA of this study, we employed a statistical package, R 4.0, which was able to determine the best-fitted model and calculate p-values for each county population.

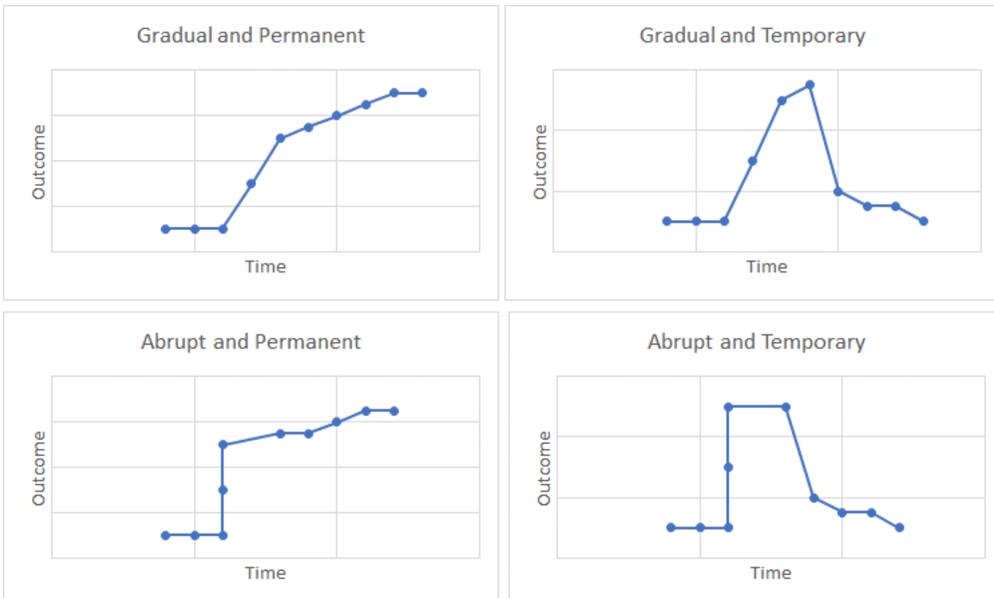

Figure 2. Impact patterns of interrupted times series [8]

3. RESULTS AND DISCUSSION

3.1. Impact of bridge on county population

Out of 124 cases investigated, it was found that 67 cases had a p-value of less than 0.05, indicating there was an impact of bridge construction on the change in county population. However, the rest (57 cases) showed that there was no bridge impact on the population change. This result suggests that unlike large-scale bridges used in the previous studies [1, 2, 3] that showed an obvious change in socio-economic factors, not all regional bridges have a similar impact on the factors. To further analyze the data, the 124 cases were sorted by three different categories: 1) route type, 2) functional class, and 3) traffic volume, and the results are summarized in Table 1.

Firstly, the number of cases for both influenced and uninfluenced for four route types: Interstate, US, State, and County highways was respectively counted. It was found that bridges coded as the US highway had the largest cases (61%) as a significant impact on population among others except for the county highway case. For the interstate highway and state highway route types, the number of no noticeable population change ($p \geq 0.05$) cases was even higher (79% and 59%, respectively) than those with an impact. One may suppose that a relatively large bridge (e.g., an Interstate or US highway bridge) would attract more people. However, the analysis showed somewhat mixed results. Therefore, it can be said that there is insufficient evidence to conclude that a specific route type has a more impact on population change than other types.

Secondly, we separated the data by the bridge's functional class (urban vs. rural) to see a discernible characteristic between urban and rural. The results indicate that, in rural areas, bridges had more cases (59%) with respect to the impact on the population than those with no impact (41%). Among the bridges located in urban areas, only 20% had an impact on population change, while a majority of the bridges had no impact on the change. Similar to the finding of the route type analysis, this result does not provide sufficient evidence to claim that bridges attract more people regardless of the bridge's functional class.

Lastly, traffic volume on the bridges was considered, creating two groups: one with less than 10,000 ADT and the other with more than 10,000 ADT. As provided in Table 1, bridges with less than 10,000 ADT had about 58% of the cases that had an impact, while the rest showed no significant impact on the population. For bridges carrying more traffic volume, only 36% of the cases had an impact. No clear impact pattern was observed by traffic volume.

Table 1. Impact of bridge on population

	Count	**Count (percentage)**	
		p-value < 0.05	**p-value ≥ 0.05**
By route type			
Interstate highway	14	3 (21%)	11 (79%)
US highway	92	56 (61%)	36 (39%)
State highway	17	7 (41%)	10 (59%)
County highway	1	1 (100%)	0 (0%)
Total	124	67 (54%)	57 (46%)
By functional class			
Urban	15	3 (20%)	12 (80%)
Rural	109	64 (59%)	45 (41%)
Total	124	67 (54%)	57 (46%)
By traffic volume			
More than 10,000 ADT	22	8 (36%)	14 (64%)
Less than 10,000 ADT	102	59 (58%)	43 (42%)
Total	124	67 (54%)	57 (46%)

3.2. Discussion

Although it was found that approximately half of the bridge construction events affected county population change, a number of cases remain uninfluenced. Therefore, we failed to reject the null hypothesis (H_0: construction of a new bridge within a county has *no* significant impact on the increase of county population), as no sufficient evidence was provided. Even with the categorization of the data by route, function, and traffic volume, the same conclusion is drawn. We find it interesting because the conclusion is not aligned with the findings reported in the previous studies mentioned earlier. Our conclusion rather suggests that not all bridge construction may have a noticeable impact on the population at a small to medium-size community level such as county.

We took the DeKalb county case to better understand the results. In this county, a bridge was constructed in 2000 as a mainline state highway in an urban area. This construction appeared to influence an abrupt population increase as shown in Figure 3. We found that the county also constructed and opened similar size bridges in 2004, 2005, and 2006. However, the last three bridge cases didn't affect the county population according to the ITSA. This may be attributed to a debilitating effect after the first impact. In other words, the impact would be more pronounced with the first event, but it would not be marked with successive events, especially when the times of events are in proximity to each other. Future research would need to delineate the first event from others to address how a series of events play a role in the change of socio-economic factors.

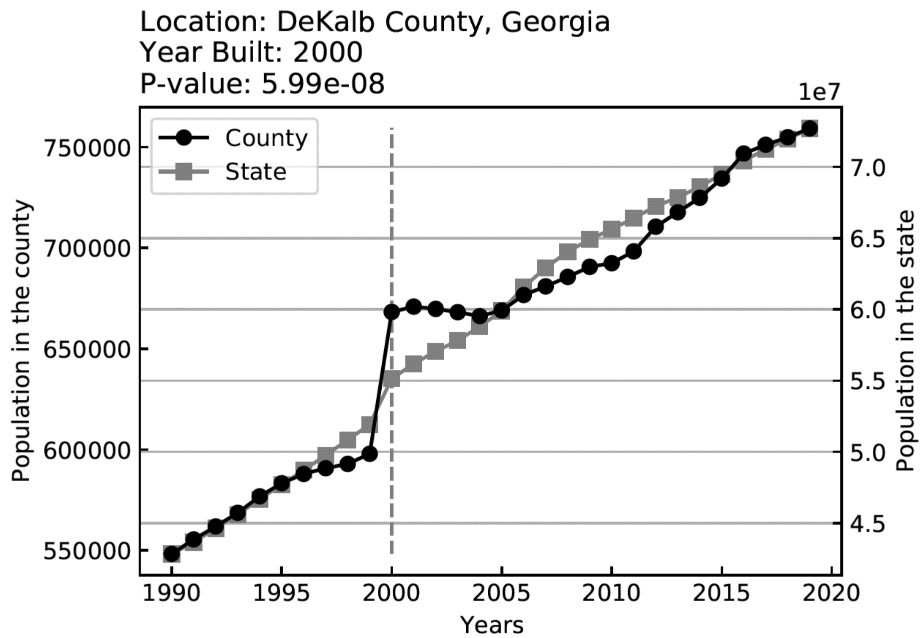

Figure 3. Population profile of DeKalb County, GA

4. SUMMARY AND CONCLUSION

The goal of this study was to detect a significant change in the human population due to new bridge construction. In particular, the study focused on the bridge construction impact on the regional population change at a county level by using the ITSA. The 124 cases consisting of 239 bridges built in 67 counties of GA in the US during the 2000s were analyzed by treating the emergence of a new bridge as a possible interruption event in the ITSA. The results showed that the population in approximately half of the cases was significantly increased due to a new bridge, although there were a number of cases that were not affected by the event.

Consequently, it is concluded that, based on the bridge and population data of GA used in this study, not all new bridge construction has a significant effect on the change in the human population at a county level. No concrete evidence was found with respect to discerning the results by route type, functional class, and traffic volume. It should be noted that this conclusion does not support the findings of several previous research where a large-scale bridge was considered.

It is recommended that future research be conducted with an expanded database that would include not only the human population, but also other socio-economic indicators such as GDP, education level, household income, real estate, or truck traffic, to name a few. Future research should also address how consecutive bridge constructions within a short time period affect those socio-economic factors.

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