Cities that Work

IGC

Cities Spatial Model

A Quantitative Spatial Equilibrium Model to guide urban planning, policy, and infrastructure investment decisions

Hugh Cole, Victoria Delbridge, Maria Del Mar Gómez, Nick Tsivanidis, and Román David Zárate

Recent academic research using structural spatial models has made breakthroughs in the evaluation of urban interventions such as new roads or Bus Rapid Transit (BRT) systems, as well as new planning regulations, land taxes, and urban regeneration projects. The IGC, together with researchers from the World Bank and policymakers from the City of Cape Town, has created an R package that operationalises these models for policy in a user-friendly format on open-source software. It requires minimal data inputs and minimal programming knowledge.

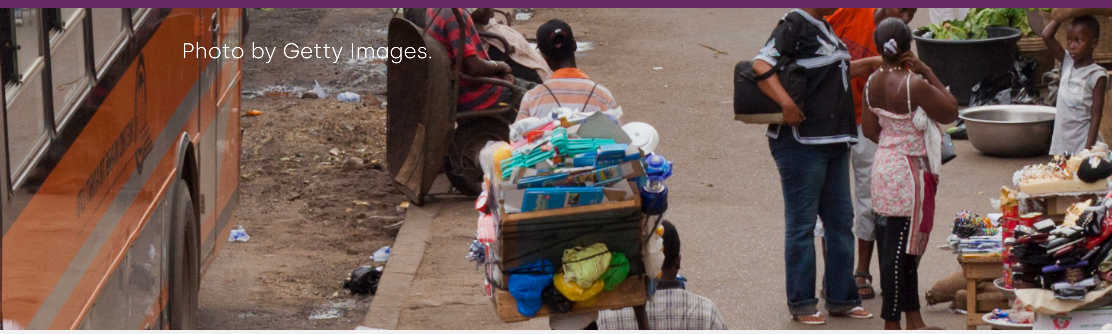


Photo by Getty Images.

JULY 2024

DIRECTED BY LSE UNIVERSITY OF OXFORD

FUNDED BY UKaid from the British people

Contents

The IGC Cities Spatial Model was produced through a collaboration with researchers from the World Bank and policy makers from the City of Cape Town. Special thanks goes to Paul Court and Alfred Moyo for their role in reviewing the model and associated outputs, and to David Zarruk for coding the first version of the package.

Policymakers in cities around the world grapple daily with challenging decisions on how to allocate scarce resources. Large and costly infrastructure investments, such as new roads or Bus Rapid Transit (BRT) systems, as well as new planning regulations or urban regeneration projects can have large and long-lasting implications for the spatial form of the city, its residents, and its economy. It is therefore imperative that city governments are equipped to make informed decisions.

Recent academic research using structural spatial models has made breakthroughs in bringing economic insights to urban policy and investment decisions. These models account for the fact that cities are complex and connected systems, such that an intervention in one location will have knock-on impacts throughout the city. They aim to shed light on how urban policies and investments change:

- Where people live and work, and the resulting commuting patterns in the city.
- The price of floorspace and the wages that are paid to workers.
- The overall economic productivity and population welfare.

> **Through simulation, policymakers can discern which policies or projects yield the highest economic returns, balancing these benefits against construction and operational costs.**

The IGC, together with researchers from the World Bank and policymakers from the City of Cape Town, has created an R package that operationalises this model in a user-friendly format on open-source software and is available for download on the CRAN repository.[1] It aims to enable policymakers in cities across the world to apply this framework to several different policy questions, with minimal data inputs, and minimal programming knowledge.

Through simulation, policymakers can discern which policies or projects yield the highest economic returns, balancing these benefits against construction and operational costs. While the current iteration of the package represents the model in its simplest form, this simplification ensures the package's applicability even in data-scarce environments while still reliably ranking policy options. Where relevant additional data is available, the model can be extended to incorporate these features.

Download the IGC Cities Spatial Model R package on the CRAN Repository.

1 The specific model used is from Alfheldt et al. (2015).

Street view of Nairobi, Kenya.
Photo by Getty Images.

APPLICATION: BRT INVESTMENT IN CAPE TOWN[2]

The City of Cape Town has been investing in building strong economic analysis capabilities to enable more informed decision making. This includes understanding the trade-off's around the allocation of infrastructure in space – the City wanted to know where such investments would yield the most benefit to society, and what impact this might have on the economy.

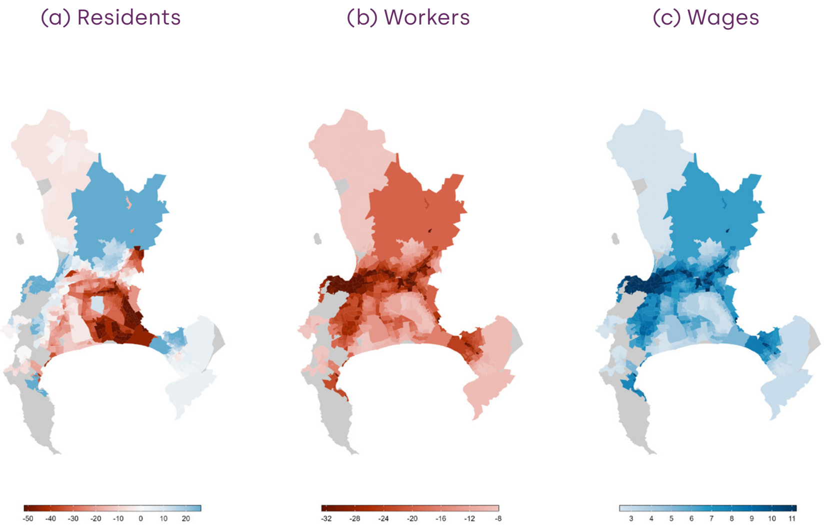
The partnership between the City and researchers enabled the creation of a tool to answer such questions, the first-use case focussing on the evaluation of the impacts of the Phase 2A extension of the MyCiti bus route.

The results showed that proximity to the new BRT line makes areas more productive, and hence we see employment opportunities shifting to these areas. Market access of consumers increases throughout the city, but most prominently next to the BRT line. Figure 1 below depicts these results.

Property prices rise across the city, but particularly in the areas adjacent to the BRT, as they benefit from improved connectivity. Overall, the welfare gained from the BRT line is 1.52%, or in local currency, an average resident would need R1888.16 ($103) additional annual income to experience the same benefit. This calculation can be used as an input into cost benefit analysis.

The tool can now be used in a variety of applications by the City itself, but has also created a public good to share with other cities around the world in need of similar insights

Figure 1: Simulation of impacts from implementing Phase 2A of the MyCiti BRT



2 Gómez, M., Zárate, R. D. (2023). Using Quantitative Spatial-Equilibrium models to inform urban policy making. IGC working paper.

What are the key inputs to the model and what data is required?

The city will need to be divided into smaller spatial units. The more granular these units are, the better the quality of the results. For each of these locations, the model will require:

- **Total area** - usually calculated using satellite imagery and aerial photography, and should exclude any protected areas that restrict development.

- **Number of residents** - often available through census or administrative records.

- **Number of workers** - often available through employment census or administrative records.

- **Average floorspace prices** - can be obtained from real estate listings, land and property registry or valuation records, or property deeds.

Some alternative methodologies, such as web scraping or use of cellular data, can also be used to obtain these variables. For example, cell-phone metadata or travel surveys may provide measures of commuting flows between locations, which can be used to estimate residential populations at origin locations or employment at destinations.

Wages are another key input to the model, and can be estimated by observing the distribution of workers and residents across the city and predicting the wages that would need to be paid to attract workers to a specific location.

The model combines this data with a **standard set of parameters**. Among others, these include the share of income typically spent on housing, the sensitivity of people to commuting costs, the relative importance of land and labour in producing economic outputs, and the relative importance of land and capital in constructing floor space. Although the impact of changes in these parameters are mostly relatively small, these can be estimated in the user's city and replaced in the model to improve accuracy.

With this information, the model can then recover three fundamental characteristics of the city in each location:

- **The level of amenities**: This refers to the non-monetary factors of a location that contribute to its desirability, such as the quality of public services (for example schools, healthcare facilities), access to recreational areas and cultural activities (for example museums, theatres), and environmental conditions (for example air quality, green spaces). These are inferred in the model by observing people's choices of where to live, given certain floorspace prices and wages.

- **The productivity**: This captures the efficiency of firms. It is affected by factors such as the available natural resources or access to good infrastructure – for example, electricity and internet in that location. This is inferred in the model by observing the number of workers, the floor space prices, and the wages.

- **The density of land development** measures how much land is developed in a particular location based on the total floor space. A location with a higher density of development implies that the location has more buildings than other areas in the city. The model recovers these by using data on floor space prices, available land, number of workers, and residents and wages.

Commuting times are another fundamental characteristic of the city, and are often measured through surveys or existing data on public transportation systems.

Together, this describes the city at baseline. To evaluate the impact of a policy or infrastructure intervention, the user needs to manipulate one of the fundamental characteristics of the city (a change in amenities, productivity, density of land development or commuting times) and compare the outcomes. For example, changing commuting speeds along a new BRT route, or increasing the amenities score to simulate neighbourhood regeneration projects.

City view over the skyline of Addis Ababa, Ethiopia. Photo by Getty Images.

Interpreting the results

The model tracks how the interventions affect the number of residents and workers, wages, and house prices in each location. It also looks at how an intervention changes the market access of residents – which measures how workers can access employment via the commuting network, as well as how firms can access workers.

According to the model's intuition, locations boasting higher productivity tend to attract more workers and economic activity due to their advantage in production, while areas offering superior amenities tend to draw residents, leading to a specialisation in housing. For example, the Central Business District of most cities, given its proximity to other businesses and logistics routes, has an advantage in production, while neighbourhoods closer to natural beauty, clean air and larger plot sizes are preferred by residents.

Wages increase where there is high demand for (or scarcity of) workers, and decrease in the event of a higher supply of workers coming in. In other words, employers need to pay workers more to work in relatively inaccessible places to compensate for the higher costs of commuting. Similarly, increased desirability for specific locations to live is expected to drive up floor space prices, as demand for housing outstrips housing development itself.

The model also describes the overall impact on welfare. Welfare increases when individuals have higher residential amenities, higher wages, lower rents, and low commuting times. Welfare can also be converted to a monetary figure that showcases the additional income that an individual would need to receive to reach a similar level of well-being. In other words, the monetary value of that policy or infrastructure investment to individuals.

Assumptions and limitations of the model

While the model enables policymakers to gain insights on areas that were previously hard to quantify, it does come with several limitations, and should therefore be interpreted conservatively and used alongside other decision-making aids.

- The model does not account for **time**. It therefore cannot give insights about the transition process when a new policy or infrastructure is put in place, and only lends perspective on the ultimate long-term effect.

- The model assumes a **representative person** in all the locations. Yet, in real life, there can be differences across gender, education level, and race. Extensions to the model can be added to overcome this, including differentiating between high and low-skill workers, or formal and informal workers.

- Similarly, the model assumes a **single production sector**. However, in reality there are several production activities that use different types of inputs and processes. This can be overcome by extending the model and adding additional data on sectors.

- The model is based on typical economic assumptions, such as **perfect competition and rationality** that are commonly used in models, but which have also been criticised for being too unrealistic.

- By assuming that **people can move freely** across locations, the model also excludes key factors of human interaction such as segregation and asymmetric information.

- The model assumes **full employment**, and does not account for drawing in inactive residents into the labour force, which could affect productivity. This can be overcome by adding a household work as a production sector.

A view over the rooftops of Kigali, Rwanda. Photo by Getty Images.

How has the model been used in other contexts?

As mentioned before, this model can be extended to accommodate richer features of the economy and overcome some of these limitations, as well as be used to explore the impacts a variety of place-based policies.

For example, similar models have been used in:

- Bogota, to assess the impact of the world's largest **BRT** – the TransMilenio.[3] The model was also used to assess how **land value capture** tools might have altered the outcomes had they been implemented at the same time. It extends the simple model by including the impact on both **high and low-skill workers** to comment on inequality and spatial segregation, and looks at the impact of the BRT on **overall congestion** in other transport modes. The model's results were also used as an input into a cost-benefit analysis of the infrastructure, showcasing TransMilenio as a highly profitable investment for the city.
    - Similar models differentiating between high and low-skill workers were used to evaluate transport infrastructure in Rio de Janeiro[4] and Buenes Aires[5].
- Mexico City, to evaluate the link between the new subway line, informality, and overall economic efficiency. It distinguishes between **formal and informal workers** to model whether transit investments have an impact on re-allocating workers from the informal to the formal economy.[6]
- Amman, to assess the impacts of two new BRT lines. It included information on **commercial and residential built floorspace as well as zoning restrictions**, which describe the maximum floorspace that can be developed in each location. This showcased how these regulations might be hindering productivity and welfare gains. It also shows how the impacts differ across **three sectors of employment: manufacturing, tradable services, and non-tradable services**.[7]
- London, to estimate **the historic impact of the railway network** on where people choose to live and work.[8]

3 Tsivanidis, J. N. (2018). The aggregate and distributional effects of urban transit infrastructure: Evidence from Bogotá's Transmilenio. *Unpublished manuscript*.
4 de Campos, M. C. (2019). Urban mobility, inequality and welfare in developing countries: evidence from 2016 Olympics in Rio de Janeiro. Doctoral dissertation, PUC-Rio. Warnes, P. E. (2020). Transport infrastructure improvements and spatial sorting: evidence from Buenos Aires. Working Paper.
5 Warnes, P. E. (2020). Transport infrastructure improvements and spatial sorting: evidence from Buenos Aires. Working Paper.
6 Zárate, R. D. (2022). Spatial misallocation, informality, and transit improvements: evidence from Mexico City. The World Bank.
7 Kleineberg, T., Murray, S., Tang, Y., Kaw, JK. (2022). The welfare and productivity effects of transit improvements in Amman.
8 Heblich, S., Redding, S. J., and Sturm, D. M. (2020). The making of the modern metropolis: evidence from London. *The Quarterly Journal of Economics*, 135(4), 2059-2133

- Kampala, to explore the **impact of land tenure systems on land use patterns and economic activity** in the city. The model incorporates both formal and informal employment and housing. It also accounts for different sectors, capturing manufacturing, business and consumer services, separating out one-person firms. High and low-skilled households are also differentiated. They account for geographical features, such as elevation and ruggedness of the land.[9]

- Japan, to **understand the welfare gains from transport interventions when including non-commuting trips** by including detailed information on travel chains.[10]

- Chicago, to look at the **welfare consequences of land use regulations** – in particular zoning and floor-to-area ratios – for low and high-skilled workers, especially their cost of housing and wages.[11]

- India, to understand the **spill-overs from high-rise developments on slum dwellers**. The model includes information on informality and evictions, and provides insights on the compensation evicted slum dwellers require to maintain a similar level of wellbeing.[12]

9 Bird, J., and Venables, A. J. (2020). Land tenure and land-use in a developing city: a quantitative spatial model applied to Kampala, Uganda. *Journal of Urban Economics*, 119, 103268.
10 Miyauchi, Y., Nakajima, K., and Redding, S. J. (2021). The economics of spatial mobility: theory and evidence using smartphone data. Working Paper w28497, National Bureau of Economic Research.
11 Acosta, C., and Submitter, C. I. E. F. (2021). The incidence of land use regulations. Centre for Research in Economics and Finance.
12 Gechter, M., and Tsivanidis, N. (2023). Spatial spillovers from high-rise developments: evidence from the Mumbai Mills. *Unpublished Manuscript*.

Cities that Work is an International Growth Centre (IGC) initiative that seeks to translate economic research and practical insight into clear urban policy guidance. Cities that Work combines new evidence and analysis of urban economics with the hardwon knowledge of urban planning practitioners and policymakers. Our aim is to develop a policy-focused synthesis of research, and a global network of individuals with a shared vision for urban policy.

theigc.org/citiesthatwork

Cities that Work

IGC