



**IMPACT CASE STUDY**  
JUNE 2022

# Forecasting urban growth and water consumption in Colombia and beyond

55% of the world's population lives in urban areas. This figure is expected to grow to 68% by 2050, with most of the growth occurring in Africa and Asia.

Effective management of urban areas is essential to achieving Sustainable Development Goal 11: 'making cities and human settlements inclusive, safe, resilient, and sustainable'.<sup>1</sup>

Cities can be places of innovation and development where residents enjoy access to services, employment, and social support. But without effective planning, urban areas may be blighted by poor housing and infrastructure, environmental damage, inequality, and pollution.

Understanding the changing footprint of urban areas is therefore vital to those planning future infrastructure and services. It can be particularly challenging in low- and middle-income countries where resources are scarce, and change happens quickly and often in unexpected ways.

New easy-to-use models, developed by the Research in Spatial Economics (RISE) Group at EAFIT University, Medellin - as part of the PEAK Urban research programme - are enabling planners to predict changes in the size and density of urban areas and build this into decision making. The models run on open access information and can be used in any context, offering the potential to transform urban planning to help create the compact, sustainable cities of the future.

Research literature shows that the effective provision of Water, Sanitation and Hygiene (WASH) is associated with better health and development outcomes and contributes directly to achieving SDGs 3 (Health), 6 (Water and Sanitation), and 11 (Sustainable Cities).

# Developing new models for predicting urban growth



The new models developed by RISE build on earlier work predicting urban growth, and a strong relationship with Empresas Públicas de Medellín (EPM), the largest public multi-utility company in Colombia.

## The background

EPM, which supplies water, electricity, gas, sanitation and other services to residents and industrial users in the Antioquia region around Medellín, initially approached RISE in 2013 to help them better predict future water demand.

RISE responded by developing 'Pascal' which uses complex mathematical modelling and detailed historical information about water connections to predict water demand. Pascal has allowed EPM to plan infrastructure and services more effectively since 2014 but its demanding information requirements, and reliance on complex rule-based modelling, makes it difficult to adapt to different contexts.

## Urban Pixel: a more flexible model

When the RISE group joined PEAK Urban in 2018, they wanted to build on their experience of Pascal to develop more accessible and flexible models to predict urban growth, in line with PEAK's objective of strengthening the capacity of cities to plan for sustainability.

Drawing on the expertise of researchers in computer vision, machine learning, remote sensing and applied maths, the group developed a new model, branded 'Urban Pixel', using freely available satellite images from the Global Human Settlement and Landsat programmes.

The data-driven model uses machine learning to analyse images and, unlike Pascal, does not assume a fixed mathematical model and requires less detailed

historical information, although it can provide richer results if additional information on terrain, population, and policy scenarios are supplied. The group tested Urban Pixel in two cities with different growth patterns and characteristics, showing how certain policy decisions (e.g., setting an ideal maximum population capacity) can result in more compact, sustainable cities. The results were published in the Remote Sensing journal (See below: Research Outputs).

## Further work with EPM

RISE recognised the potential of the new model for EPM and approached the company again in 2019. EPM were extremely interested and asked them to develop the algorithm into a bespoke tool to predict water demand in any context, even where they had no prior experience of the market. The RISE team quickly developed 'Newton' which predicts water need from urban growth forecasts using satellite images, and trained colleagues at EPM to run the software. The model was featured in a national Colombian media article<sup>2</sup> in June 2021.

## Pathways to impact

The underpinning research, development of the Urban Pixel and Newton tools, and work with EPM to embed the model in policy and practice are all based on PEAK Urban's Theory of Change and contribute to its 'Pathway to Impact', as detailed below:

### 1. Conceptual advancement results pathway: New knowledge

Programme expected result: Better informed policy, Practice and Investment decisions contribute to strengthening capacities of cities to deal with 21st century development problems. Findings are shared with, and accessible to key stakeholders and non-specialist audiences.

*“Now it is easy for us to predict future water demand in our existing markets or those we want to explore. We can download satellite images, feed them into the model, and quickly get a detailed report on how an urban area is growing and what this means for water consumption in 20, 30, or 40 years.”*  
**Juan Camilo Hurtado,**  
*Planning Professional, EPM*

EPM is aware that the effects of using the Newton model will only be measurable in 5-10 years, once the models have been implemented and the impact formally evaluated. The company has however already identified current and expected benefits to its business, and to wider stakeholders including consumers, planners, and the environment.

**Benefits to EPM**

Juan Camilo Hurtado, Planning Professional in EPM’s Directorate of Water and Sanitation Planning comments: “The provision of water and sewage infrastructure is often based on poor estimates of where and when it might be needed in future. If people do not move to an area as quickly as expected it could be years before the facilities are used and begin to generate a return. Newton allows for accurate ‘in time’ planning, making sure the infrastructure we build meets actual future demand. This will enable us to improve the efficiency, value for money, and quality of our services – and help us move into new markets with confidence.”

- EPM is now running Newton in urban areas close to Medellin where it already supplies water, to help it better understand how to use the model in practice and ultimately to improve services and plan future provision.
- In future, the company intends to use the model to develop proposals to enter new markets outside Colombia. The model will give EPM a high degree of confidence about future demand (around 80%) and the infrastructure required to meet it.
- As the company also supplies energy, gas and other services, the water and sanitation team recognise the potential to adapt the model to predict demand for other utilities, benefiting the wider organisation and an increased number of service users.
- The work with RISE has also enabled the EPM team to develop new skills, knowledge, and perspectives.

Five experienced team members worked closely with the researchers over seven months to adapt and develop the model, blending EPM’s intuition and specialist market knowledge with the data-driven modelling approach in a rewarding collaborative process.

**Benefits to other users**

Hurtado and his team have also outlined the future benefits for consumers, planning authorities, and the environment that EPM anticipates from using the models.

- **Water consumers:** Residents and industrial users should benefit from more cost-effective and appropriate services. Water tariffs should be lower where infrastructure is built at the right time and in the right place to meet need. Cheaper water may mean provision can be extended to areas without formal water services in new markets. Reliable access to high-quality water and sanitation will benefit the overall health and wellbeing of urban dwellers.
- **Urban planners and local authorities:** EPM believes the model will be of great benefit to the urban planners and local authorities they work with. “Municipal authorities usually base their predictions on intuition,” explains Hurtado, “but it’s useful to have a tool to help them plan more precisely. The tool can help ongoing conversations with policy makers about their plans. What kind of city do they wish to see? What action should they take to achieve this?”
- **The Environment:** The ability to predict future urban growth enables planning authorities to identify areas for development, whilst protecting the environment. Ensuring that all infrastructure built is actually needed to meet water and sewage demand will reduce the environmental impact of unnecessary or inappropriate development. More sensitive and precise planning will ensure building does not adversely impact aquifers and affect groundwater supply. It will also allow denser, more sustainable, development within designated residential/industrial areas, whilst preserving identified spaces for recreation and environmental regulation.

**1.2 Conceptual advancement results pathway: New knowledge**

Programme expected result: New knowledge generated by PEAK Urban leads to conceptual advancement in the understanding of challenges and opportunities faced by 21 Century Cities: A body of high quality, interdisciplinary research is produced by Peak Urban; Research is accessible to and accessed by research communities, particularly in the global south.

## Research outputs

On the theme of urban growth, the RISE group have published the following academic papers from their research as part of the PEAK Urban programme. A number of other papers are in development.

- **Journal Article:** Gómez, J. A., Patiño, J. E., Duque, J. C., & Passos, S. (2020). Spatiotemporal modelling of urban growth using machine learning. *Remote Sensing*, 12(1), 109. Available at: <https://www.mdpi.com/2072-4292/12/1/109>
- **Journal Article:** Gómez, J. A., Guan, C., Tripathy, P., Duque, J. C., Passos, S., Keith, M., & Liu, J. (2021). Analyzing the Spatiotemporal Uncertainty in Urbanization Predictions. *Remote Sensing*, 13(3), 512. Available at: <https://www.mdpi.com/2072-4292/13/3/512>
- **Journal Article:** Duque, J. C., Lozano-Gracia, N., Patino, J. E., Restrepo, P., & Velasquez, W. A. (2019). Spatiotemporal dynamics of urban growth in Latin American cities: An analysis using night-time light imagery. *Landscape and Urban Planning*, 191, 103640. Available at: <https://doi.org/10.1016/j.landurbplan.2019.103640>

## Research sharing

The RISE group have produced the following public-facing publications from their research as part of the PEAK Urban programme. A number of others are in development.

- **Research Brief (English):** [Towards a more sustainable urban growth through a data-driven framework for modelling, planning and control, June 2020](#)
- **Research Brief (Spanish):** [Hacia un futuro mas sostenible a través del modelado, planificación y control de crecimiento urbano basado en datos June 2020](#)
- **PEAK Urban blog:** <https://www.peak-urban.org/blog/how-will-our-cities-grow-future-new-approach>
- **PEAK Urban blog:** <https://www.peak-urban.org/blog/causal-inference-and-its-importance-sustainable-urban-growth>
- **PEAK Urban videos on YouTube:**  
<https://youtu.be/k91MdLxLSiU>  
[https://www.youtube.com/watch?v=9A-FN42r\\_6U](https://www.youtube.com/watch?v=9A-FN42r_6U)  
<https://soundcloud.com/user-40366602/desafios-de-las-ciudades-en-expansion-y-el-crecimiento-urbano>

## 2. New ways of working pathway

Programme expected result: Researchers and urban actors work effectively together, overcoming functional and disciplinary silos. Cohort of researchers has increased ability and networks to work across disciplines on key urban themes.

The EAFIT/PEAK Urban project has generated new ways of working, and lead to new networks, relationships and collaborations working on urban issues in Colombia and globally.

**Working across disciplines:** Innovative collaboration between experts in computer vision, machine learning, remote sensing, and applied maths was key to the development of both Urban Pixel and Newton and will underpin further iterations of the tools.

“In Colombia, researchers normally work only in their specific area,” says Jairo Alejandro Gomez Escobar who led the research team. “We brainstormed the problem we wanted to address with researchers with very different expertise, which helped us to think creatively, break down boundaries, and develop innovative solutions in a very short time.”

**New research relationships:** Support from the core team at the University of Oxford has helped facilitate wider contacts in the PEAK Urban team and extend the perspectives and research ambition of the Colombian team.

The group is now collaborating with PEAK Urban colleagues in China (Shanghai University) and India (Indian Institute for Human Settlement), further extending their research network and learning from new contexts and approaches. A forthcoming paper resulting from the collaboration has compared the Urban Pixel model with commonly used SLEUTH to predict urban growth in two small cities in China.

**New networks:** PEAK Urban has also allowed RISE researchers to extend their networks beyond academia, to public sector organisations such as EPM as well as to international institutions including the World Bank. A new collaboration with the World Bank is now using Urban Pixel to predict where, and when, new metropolitan areas in Latin America will emerge – and will help anticipate and meet demand for services in fast-growing urban areas.

### Acknowledgments:

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### References:

1. <https://sdgs.un.org/goals>
2. Article can be found at: <https://www.eltiempo.com/colombia/medellin/innovacion-paisa-permite-predecir-el-crecimiento-urbano-de-las-ciudades-593757>
3. Evaluation interview with Juan Camilo Hurtado of EPM and the Peak Urban team on 28 April 2021 (by Zoom)

Publication: This case-study reflects information gathered up to 6 June 2021. For latest updates contact Juan Carlos Duque at [jduquec1@eafit.edu.co](mailto:jduquec1@eafit.edu.co)

## Value for money

Promoting interdisciplinary research, developing practical tools, and engaging stakeholders to improve urban growth forecasting and enable better planning for sustainable cities.

*“We believe that these urban growth models will give public authorities a better sense for where their cities are growing and more time to plan and design the necessary actions to anticipate this growth.”*

*Juan Carlos Duque, RISE research group, EAFIT.*

### Economy test

The new models have been developed economically by building on existing research and relationships; drawing on the expertise and talent of university researchers at all levels (including undergraduates where appropriate); and using publicly available data and images. By publishing a paper in the prestigious Remote Sensing journal, the team had an early and cost-effective proof-of-concept to take to companies to discuss commercial development.

The potential gains from the use of the models are extremely significant, although it is difficult to quantify return on investment at this stage. Compact, sustainable cities providing quality services and balancing the needs of residents, the economy, and the environment could be transformative for health and development in the next decades.

### Efficiency test

Policymakers often rely on intuition and rule-based models to forecast urban growth; but these can only offer rough approximations of growth, cannot indicate future density of particular areas, and don't take account of scenarios that are not actively considered. The RISE models allow policymakers and planners to forecast growth across time and space, and to compare the outcomes of different policy choices – offering an effective solution for planners in low- and middle-income countries.

Development from concept to commercial product was achieved in around two years – demonstrating a fast and effective process, drawing on multiple sources of knowledge, collaboration, and expertise.

### Equity test

The development of the models included numerous researchers from the global South, including early career researchers who were trained and supported to develop their research skills, capacity, and experience.

Across the PEAK Urban partnership, 41 of the researchers are women and 61 are men.

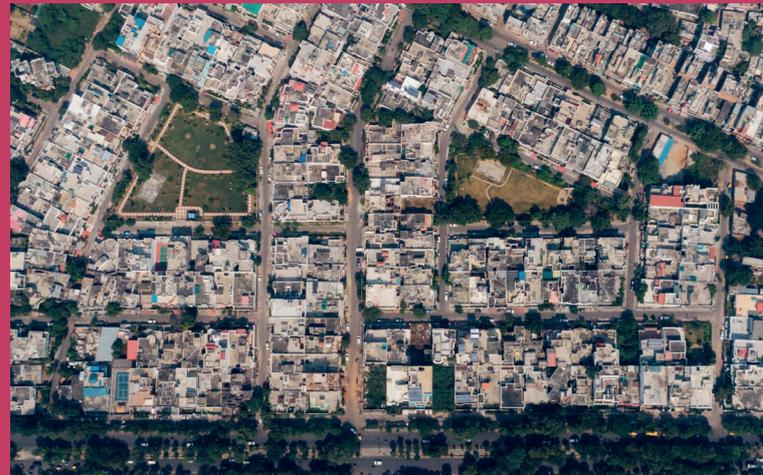
Use of the model by policy makers and practitioners should lead to higher-quality, lower-cost, more appropriate services which will benefit low-income urban dwellers particularly women who are often responsible for domestic and care-related activity and depend on good public services, and children for whom water and sanitation are vital to good health outcomes.

### So what?

Using evidence-based planning, policymakers and service providers can maximize the benefits of urban growth and minimize its adverse impacts, ensuring cities are sustainable, inclusive, and resilient (SDG 11), whilst balancing the need for economic development and environmental protection.

The models developed by RISE, and practical tools such as Urban Pixel and Newton, provide an important contribution to such evidence-based planning. The models can be run by non-experts, using free, publicly available information. They are particularly appropriate for use in challenging and resource-constrained contexts, offering huge potential for future uptake.

The RISE group's ability and ambition to market the tools to potential clients, train and support stakeholders to use them, and to help embed the research in policy and practice, means that the models have the potential to transform urban planning far beyond the original research site and stakeholders.



## About us

The PEAK Urban programme aims to aid decision-making on urban futures by:

1. Generating new research grounded in the logic of urban complexity;
2. Fostering the next generation of leaders that draw on different perspectives and backgrounds to address the greatest urban challenges of the 21st century;
3. Growing the capacity of cities to understand and plan their own futures.

In PEAK Urban, cities are recognised as complex, evolving systems that are characterised by their propensity for innovation and change. Big data and mathematical models will be combined with insights from the social sciences and humanities to analyse three key arenas of metropolitan intervention: city morphologies (built forms and infrastructures) and resilience; city flux (mobility and dynamics) and technological change; as well as health and wellbeing.

## Contact

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## Our framework



The PEAK Urban programme uses a framework with four inter-related components to guide its work.

First, the sciences of **Prediction** are employed to understand how cities evolve using data from often unconventional sources.

Second, **Emergence** captures the essence of the outcome from the confluence of dynamics, peoples, interests and tools that characterise cities, which lead to change.

Third, **Adoption** signals to the choices made by states, citizens and companies, given the specificities of their places, their resources and the interplay of urban dynamics, resulting in changing local power and influencing dynamics.

Finally, the **Knowledge** component accounts for the way in which knowledge is exchanged or shared and how it shapes the future of the city.

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PEAK Urban is a partnership between:

