

**Traffic Congestion, Health Services Accessibility, and Equity:
A People-Centred, Data-Driven Approach to Urban and Health Planning
Test Cases for Acute and Chronic Care Accessibility in Cali, Colombia**

Luis Gabriel Cuervo Amore

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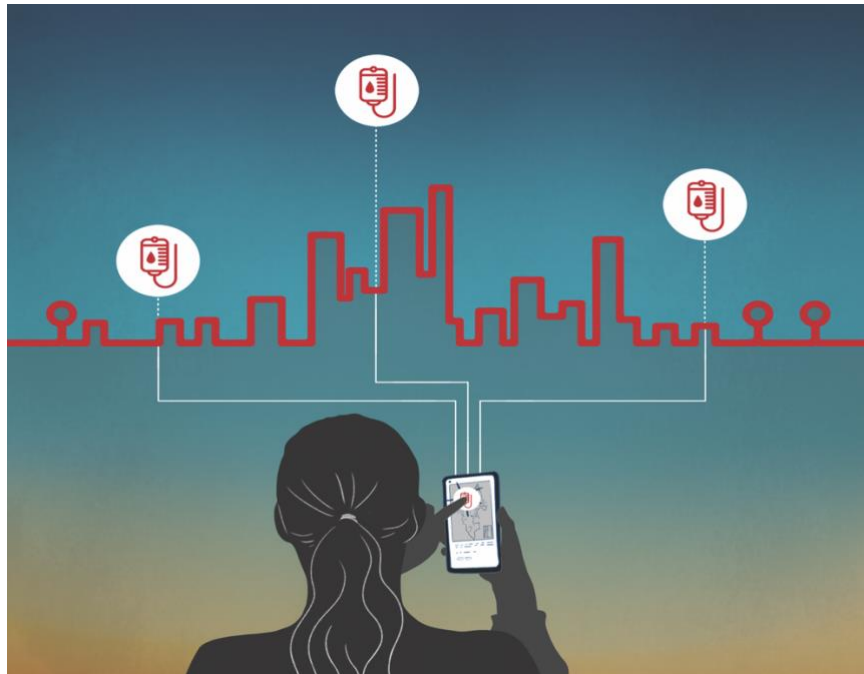
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Dedication

I am grateful to my family, friends, mentors, colleagues, peer reviewers, and editorial teams for their support throughout the development of this doctoral work.

Over the five years of my doctoral journey, I benefited from the sustained support of my nuclear and extended family, from the inspiration provided by the memory of my late parents and other family members, and from the constant encouragement of my wife, daughters, and close friends. I learned continuously from peers and colleagues who believed in the project and contributed to the formation of a committed and multidisciplinary group of collaborators. Their engagement enriched the work, challenged its assumptions, and supported its dissemination and impact.

I am particularly thankful to the peer reviewers and editorial teams who engaged with this work with rigour and generosity, as well as to partners, work colleagues, and experts who offered valuable insights at different stages. Their constructive critiques, suggestions, and editorial guidance were instrumental in strengthening the analyses, clarifying key messages, and improving the overall quality and coherence of the thesis.

Longstanding friends and professional peers facilitated access to new and stimulating collaborations. My tutor, long-term peer, and collaborator, Xavier Bonfill, provided wise counsel and steady support, particularly during demanding administrative periods and institutional challenges, helping to ensure that the work progressed and matured.

I was privileged to collaborate closely with Eng. Ciro Jaramillo, whose clarity of thought and commitment to improving his city were a constant source of inspiration. Eliana Martínez contributed to keeping the work firmly anchored in principles of social justice and meaningful participation. Every co-author and collaborator contributed generously and thoughtfully to this endeavour. I could not have asked for better thesis directors, whose guidance enriched the experience throughout the process and whose support remained unwavering.

Beyond formal academic settings, I benefited from enriching exchanges with patients, collaborators, and friends, including Felipe Piquero, as well as from the enduring influence of my late mentors, family physician Dr Arnoldo Bromet and urbanist Arq. Enrique Sinisterra O’Byrne. Their legacies continue to inform my intellectual curiosity, professional practice, and sense of purpose.

Finally, I express my deepest gratitude to my wife, Marifer, and to my brother Daniel for their steadfast support throughout this journey. Their confidence and encouragement were essential to the completion of this work.

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I am deeply grateful to the many contributors, key informants, and colleagues who generously shared their insights and encouraged me to pursue and complete this work. Among them, special recognition is due to those who formally joined the AMORE Project as contributors.

I would also like to thank IQuartil SAS for their invaluable support, innovative ideas, technical guidance, and for hosting the platform that underpinned this project. I am especially grateful to Eng. Luis Fernando Pinilla, Eng. Pablo Zapata, Ignacio Pérez, Pedro Benítez, Beatriz Helena Cuervo, Lizardo Vanegas, and Sarita Luna for their dedicated contributions.

The Universidad del Valle’s School of Public Health, the School of Civil Engineering and Geomatics, and the Faculty of Health engaged enthusiastically with the project, actively promoting its implementation, encouraging complementary research, and advocating for its integration into public policy and the social appropriation of knowledge.

I am particularly grateful to the GREAT group and the Universidad del Valle’s Populab team for fostering knowledge exchange and collaboration, and for sharing

testimonies and lived experiences from Commune 18. Special thanks also go to Dr Diana Cuervo and Felipe Piquero, Esq., for documenting testimonies from diverse actors, including their own, for conveying patient and personal experiences, and for their continued support. Other contributors shared lived experiences as service users, network organisers, or participants in decision-making processes throughout the project, including accounts of accessing tracer services as patients or carers.

At an early stage, while considering the development of this project, we created a WhatsApp group that became an inspiring and diverse sounding board. Lyda Osorio, a long-standing collaborator, was the first to join, followed by Ciro Jaramillo, who later became my thesis director. Together with peers and students who commented on the project, they contributed local knowledge and valuable insights during its formative stages. I was also privileged to exchange ideas with many other colleagues and peers, including Juan Manuel Anaya, Magaly Blas, Jan and Iain Chalmers, Beatrice Halpaap, Jini Hetherington, Mercedes Rumi, Rocío Sáenz, Joe Tucker, and many others.

This doctoral project also enabled the development of meaningful personal and professional relationships, most notably with Eng. Ciro Jaramillo Molina, my first thesis director, with whom I met weekly for more than five years. Our collaboration evolved through sustained academic exchange and mutual learning. This relationship was further enriched when Eliana Martínez Herrera joined as co-director, with whom I also developed a close, productive, and complementary collaboration.

Team 33 built on my work and brought the first versions of the platform to life, translating plans into operational tools through four intensive months of weekly collaborative sessions. Their success as finalists in the DS4A programme provided confidence, a strong foundation, and a robust methodological approach. I am grateful to Team 33 members Daniel Cuervo, Catherine Cabrera, Darío Mogollón, Juan G. Betancourt, Stephanie Rojas, Rafael Roper, and Santiago Tobar. Carmen Juliana Villamizar proved to be an exceptional project manager, and I am honoured by her decision to dedicate her capstone paper to this work.

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I am equally grateful for the constructive and thoughtful observations offered by Professors Melanie Lowe and Nasreen Jessani. Their feedback was both precise and timely, and it directly informed several of the improvements reflected in this final version of the thesis. I particularly appreciated that, alongside identifying areas for improvement, they also highlighted the strengths of the work and aspects that merited greater emphasis.

This doctorate was pursued while the author was employed at the Pan American Health Organization. The author alone is responsible for the views expressed in this thesis, which do not necessarily represent the decisions, policies, or positions of the Pan American Health Organization.

[CHAPTER SEPARATION - SPACE INTENTIONALLY LEFT BLANK]

Declaration of authorship and originality:

I, Luis Gabriel Cuervo Amore, hereby declare that the doctoral thesis entitled “*Traffic Congestion, Health Service Accessibility, and Equity: A People-Centred, Data-Driven Approach to Urban and Health Planning*”, submitted for the degree of Doctor of Philosophy within the Doctoral Program in Methodology of Biomedical Research and Public Health at the Universitat Autònoma de Barcelona, is the result of my original work.

This thesis has been conducted independently and represents an original contribution to knowledge supported by open-access publications. It has not been submitted previously, in whole or in part, for any other academic degree or qualification at this or any other institution.

Other authors' sources of information, data, results, images, or texts have been appropriately acknowledged and cited following academic and ethical standards. Any collaborations, assistance, or external contributions to the research have been duly recognised in the appropriate sections of the thesis. I wrote this document and used generative artificial intelligence (AI) and AI-assisted technologies (Grammarly, ChatGPT) to improve the readability and language.

I further declare that the research complies with the ethical principles and guidelines established for biomedical research involving human subjects, ensuring data confidentiality and responsible conduct of research, as required by the Universitat Autònoma de Barcelona and applicable national and international standards. I also sought guidance from PAHO's Ethics office to fulfil my professional obligations. The project was cleared on September 16, 2022, by the Commission on Ethics in Animal and Human Experimentation (CEEAH), and the Vice-Rector for Research, Universitat Autònoma de Barcelona (Ref: CEEAH-6100) on September 20, 2022. It was also cleared in Colombia on July 25, 2022, by the Research Ethics Committee of the School of Engineering at the Universidad del Valle, which declared the project “without risk” in accordance with Colombian law (Ref: CEIFI 010-2022).

I am fully aware that any breach of the principles of authorship and originality may lead to the annulment of this thesis and the withdrawal of the doctoral degree awarded.

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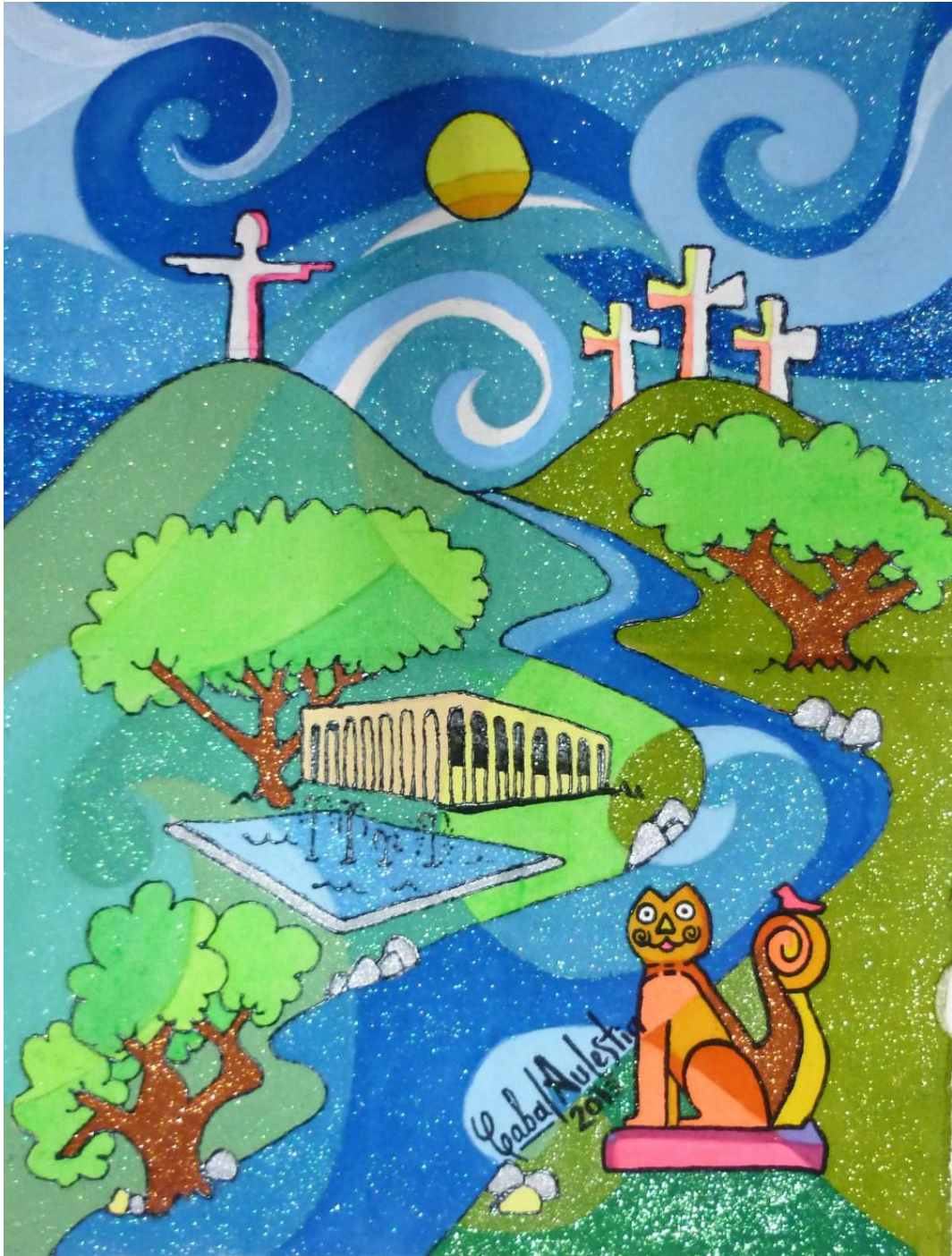


Image 1: A painting representing Cali used in our presentations, with permission from Adriana Cabal Aulestia, the artist and copyright holder.

Abstract

Background: Traffic congestion restricts timely access to health services, worsening health inequities. Existing tools to measure or predict accessibility are often costly, highly specialised, and ill-suited to intersectoral decision-making. Advances in open georeferenced data (e.g. census, health service registries), big data, and participatory, people-centred approaches now allow the creation of policy-ready cartography and metrics to guide equitable service planning.

Objective: To develop and test, in urban Cali (Colombia), a participatory, low-cost methodology to measure and predict the impact of traffic congestion on access to critical health services—tertiary emergency care, haemodialysis, and radiotherapy—integrating equity considerations and ensuring usability for intersectoral decision-making.

Methods: This doctoral research, presented as a compendium of publications, applied spatial analysis, open and big data, and principles of implementation research. The doctoral candidate led the co-design of the AMORE Platform, a web-based interactive tool integrating geographic information systems (GIS), traffic application programming interfaces (APIs), and socio-demographic data to conduct dynamic travel-time assessments and predictions. A key innovation was engaging a large, diverse group of knowledge users and interest-holders to co-conceptualise, design, and test the platform, ensuring outputs, like maps and data visualisations, were accessible to all actors and useful when debating about urban and health service planning.

Results: Congestion disproportionately affected peripheral, low-income, and some ethnic minority populations, reducing access to services concentrated in affluent, low-density sectors. Dynamic models showed that strategically placing services in densely populated eastern districts could substantially reduce travel times and inequities. Visual tools and spatial metrics supported scenario modelling and informed policy dialogue. The methodology can be scaled, replicated, and applied to close-to-real-time evaluation and long-term planning.

Conclusions: This unfunded doctoral project delivered a participatory, equity-focused, scalable method for assessing and improving accessibility in congested cities. It produced policy-oriented data and cartography that have influenced land-use planning and policy in Cali and offers a transferable model for developing accessibility metrics in other urban contexts. The work demonstrates the value of combining spatial analysis, participatory governance, and health equity to align urban and health service planning.

Keywords: Urban health, Geographic accessibility, Traffic congestion, Health equity, Spatial analysis, Open data, Participatory research, Implementation science, Colombia, SDGs, SDG3, SDG5, SDG10, SDG11, SDG16, SDG17. Intersectoral action.



Figure 1: Hand-drawn contribution donated in 2024 by the late Arq. Enrique Sinisterra O'Byrne, an urbanist, emeritus professor at Universidad del Valle, and collaborator for this doctoral project (AMORE Project).

1 Introduction

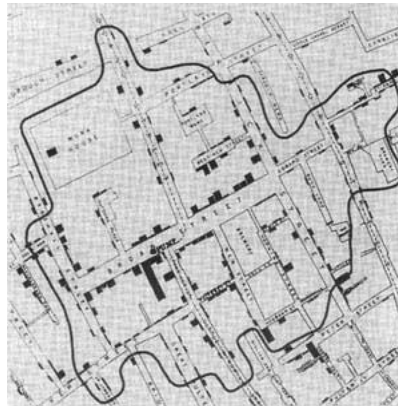
Public health has long relied on spatial analysis to reveal patterns invisible to the naked eye and to turn those patterns into action. From early disease maps to modern digital dashboards, mapping has served as both a diagnostic tool and a catalyst for change—bringing together evidence, decision-makers, and communities to address shared challenges.^{1,2}

This doctoral project extends that tradition through an innovative, data driven and participatory approach to evaluating and improving accessibility (see Glossary, section 9.2), understood as an individual's ability to travel and participate in activities given the available transport and land use system, and operationalised here using travel time to destination as a proxy, within congested urban settings (see Glossary entry on traffic congestion). It applies advances in geospatial technologies, open georeferenced data on housing, populations, and health services, and high-volume, real-time travel-time data to generate policy-ready evidence.³⁻⁵ The central question is urgent and underexplored: how does traffic congestion affect equitable access to essential health services?^{3,6} The study focuses on urban Cali, Colombia, a large, diverse, and rapidly growing city with significant challenges in transportation, health systems, and equity, offering a test case with direct policy relevance.^{6,7}

The value of such approaches becomes clearer when viewed through a historical lens. One of the most frequently cited examples comes from mid-nineteenth-century London, where the physician John Snow and the Reverend Henry Whitehead investigated one of the city's most severe cholera outbreaks. In 1854, the inner-city district of Soho became the epicentre of an epidemic that killed hundreds within weeks. At a time when miasma theory dominated medical thinking, Snow systematically mapped cholera deaths alongside the locations of public water pumps, revealing a marked concentration around the Broad Street pump. He also examined the journeys made and the time people spent travelling to collect water (Map 1). Whitehead's detailed interviews with local leaders and residents gave momentum to Snow's spatial findings, helping to mobilise support across different

constituencies. The subsequent removal of the pump handle was followed by a rapid decline in cases. Together, their work demonstrated how mapping, combined with local knowledge and rigorous analysis, could challenge prevailing assumptions and inform decisive public health action.¹

The urgency of implementing innovations is just as crucial today as it was in Snow and Whitehead's time. While delayed action may eventually lead to similar insights, the costs of inaction, especially regarding traffic congestion and its effects on healthcare accessibility, are substantial, with real consequences for individuals, families, and communities.² Traffic congestion is a pervasive and often overlooked force shaping urban life.⁸ Although it has become normalised, its impact remains harmful, hidden in plain sight and, importantly, manageable.



Map 1: "His next ingenious step was to represent the time it took to travel to the Broad Street pump on his map and to calculate who was most likely to use each water pump in the area. Snow drew a curve on the map that marked the points where the Broad Street pump was at equal walking distance from neighbouring water pumps." ² "It was, as the historian Tom Koch astutely notes, a map organized as much around time as around space: instead of measuring the exact distance between two points, it measured how long it took to walk from one point to another."¹

Johnson's reflection on Snow's contributions also resonates with this work:

"No doubt science would ultimately have come around to the waterborne theory, but it might well have taken decades longer without the clarity and reproducibility of the Broad Street story and its accompanying map. How many thousands more might have died in that interval?"¹

This thesis follows the tradition of Snow and Whitehead but adapts it for the complexities of contemporary urban life. Where their maps were static, this project delivers an interactive, web-based platform, the AMORE Platform, co-designed with a diverse group of interest-holders, including urban planners, health authorities, service providers, civil society representatives, academics, and data scientists. The platform integrates geographic information systems (GIS), traffic application programming interfaces (APIs), and socio-demographic data to assess and forecast accessibility under varying conditions. Its participatory design ensures that outputs—maps, metrics, and scenario models—are understandable, relevant, and actionable, allowing interest-holders to test options, identify priorities, and align urban and health service planning with the shared goal of greater equity.^{9,10}

Building on this foundation, the thesis adopts a compendium-of-publications format to present the conceptual development, testing, and application of the AMORE Platform. The methodological framework combines spatial analysis, open and big data integration, and principles of implementation research.^{5,11–21} The research process was structured to ensure early and continuous engagement with interest-holders, embedding their priorities into the platform's design and validation.^{22–28} Data sources included official georeferenced registries of health facilities, population and housing census data, and dynamic travel-time estimates drawn from traffic APIs. Analytical procedures incorporated GIS for spatial modelling, statistical methods for equity analysis, and scenario-based modelling to explore alternative service configurations. By integrating these methods within a participatory process, the project sought not only to generate robust evidence but also to embed it in the decision-making processes of urban and health service planning.⁶ People naturally describe journeys in terms of travel time and often consider congestion, yet planning continues to overlook this reality.

“La casa de los cuáqueros quedaba a 20 minutos de distancia y fue Roser quien les abrió la puerta” [The Quaker's house was at a 20-minute distance, and it was Roser who opened the door for them].^{Footnote 1}

This thesis demonstrates that citywide estimates of travel times, accounting for traffic congestion, are technically and economically feasible through the integration of open and big data, a reality that remains overlooked in urban and health services planning. The thesis is organised as follows. **Chapter 1** presents the conceptual background and rationale for the study, situates it within the literature on spatial analysis, health equity, and urban accessibility, and introduces the policy and research gaps the project addresses. **Chapter 2** outlines the research objectives. **Chapter 3** describes the methodological framework, including data sources, spatial modelling techniques, and participatory processes used in the co-design of the AMORE Platform. **Chapter 4** presents the core publications that comprise the compendium, each focusing on a specific aspect of the research: the integration of open and big data to assess dynamic accessibility; the equity impacts of traffic congestion on access to tracer health services; and the use of scenario modelling to inform intersectoral planning. It also highlights the results. **Chapter 5** offers an integrative discussion including limitations, future research directions, and considerations for implementation. It also provides a reflection on the methodology's implementation and scalability. The thesis lists recommendations for applying this approach in other congested urban contexts to improve equity in health service accessibility. In **Chapter 6**, it synthesises the thesis's contributions to policy-oriented knowledge and to the development of approaches to health services accessibility research.

This doctoral research advances the core objectives of the PhD programme in Biomedical Research Methodology and Public Health at the Universitat Autònoma de Barcelona. It applies rigorous methodological tools, including spatial analysis,

¹ Isabel Allende, Largo Pétalo del Mar. [A Long Petal of the Sea] Capítulo 5 - 1939. (2019) ISBN 978-84-01-02339-2

epidemiology, and integrated knowledge translation, to address real-world challenges in health equity, service accessibility, intersectoral collaboration, and the social appropriation of knowledge.^{29–36} Its execution required sustained cooperation with interdisciplinary teams, active engagement with interest-holders, and the mobilisation of networks and resources across sectors and institutions.^{37,38} By combining data-driven insights with people-centred approaches, the thesis contributes to improving population health, strengthening public health systems, and informing evidence-based policies, hallmarks of the program’s mission.

Scientific Foundations

- **Geospatial Modelling of Accessibility:** The project utilises Geographic Information Systems (GIS) to estimate realistic travel times to healthcare services, considering traffic congestion and other urban dynamics. Isochrones and spatial metrics enable both visual and quantitative assessments of accessibility.^{39–45}
- **Integration of Public Open and Big Data:** This involves integrating open, interoperable datasets from national censuses, healthcare provider registries, traffic analysis zones, and big data travel times derived from the Google Distance Matrix API.^{4,46–48}
- **Application of Public Health and Policy Frameworks:** The project adopts a people-centred approach, drawing from design thinking, implementation research, and integrated knowledge translation. It is synergic with the Sustainable Development Goals (SDGs) and the 2024 WHO Strategy for Urban Health, supporting land-use planning, promoting intersectoral governance, and maintaining a strong focus on equity.^{10,37,49–53}
- **Replicable and Scalable Methodology:** A web-based interactive platform facilitates the broader application of the methodology to other cities and service types. Its modular structure supports scenario analysis, comparative studies, and local adaptation by knowledge users. Annexe 9.10 lists some open-access sources that could assist replication in other cities.^{9,54}

The increased availability of open and big data, coupled with geographic information systems, enables reliable travel time estimates that account for traffic congestion from an equity perspective.^{3,4,6,45} During the conceptualisation of this doctoral project, we noticed that most emerging studies in this field lacked knowledge users' and interest holders' input and other considerations, such as simplicity and interactivity, which could make them suitable for translating findings into public policy, intersectoral action, and people-centred solutions.^{3,6,9,14,29,55,56}



Figure 2: Sustainable development goals that will likely benefit from improved accessibility to critical health care.

This thesis, which addresses the policy challenge of monitoring and enhancing access to essential health services in cities with significant traffic congestion, contributes directly to the United Nations' Sustainable Development Goals (SDGs) outlined in the 2030 Agenda (Figure 2).⁵² Most prominently, it supports SDG 3 (Good Health and Well-being) by generating assessments that inform equitable access to essential health services, while also advancing SDG 9 (Industry, Innovation and Infrastructure) and SDG 11 (Sustainable Cities and Communities) through innovative, evidence-based tools for urban and health service planning. Explicitly addressing inequities contributes to SDG 10 (Reduced Inequalities) and SDG 13 (Climate Action). At the same time, its participatory and intersectoral ethos resonates with

SDG 16 (Peace, Justice and Strong Institutions) and SDG 17 (Partnerships for the Goals). The detailed mapping of this work to some SDG indicators is presented in Annexe 9.14

Although travel time is the most intuitive way for urban dwellers to describe the length of commutes and journeys, the metrics, measurements, and monitoring systems required to assess accessibility in traffic-congested urban areas remain underdeveloped. These measures are largely absent from Sustainable Development Goal indicators and lack standardisation, thereby limiting their usefulness for monitoring inequities and holding decision-makers accountable.^{57,58} Addressing this policy gap requires intersectoral action, as urban health outcomes are shaped by infrastructure, geography, and transportation systems.^{59,60} Policymakers, knowledge users, and other interest holders must therefore collaborate to align and shape urban and health agendas.^{10,22,61,62} Such alignment depends on access to appropriate data and analytic insights that support meaningful dialogue, negotiation of shared objectives, and a shared understanding of the structural drivers of inequity.^{9,60,63,64}

Addressing this challenge is not merely about providing data (as John Snow did); it requires bringing the issue into the realm of democratic policymaking (as Henry Whitehead demonstrated).¹ It involves creating processes that amplify the voices and needs of diverse interest holders, ensuring that their perspectives are reflected in the data and knowledge used to inform change. To this end, we integrated principles of people-centred design, implementation research, and knowledge translation in the development of technological tools to measure and predict accessibility, focusing on a series of case studies involving selected health services. To raise awareness of the policy challenges, participants at engagement events were greeted with banners displaying a two-dimensional map of Cali, marked with existing service locations. They were asked to indicate one or two places where they would add new services. This visual and straightforward exercise sparked discussion and revealed how limited awareness of population distribution and travel times can lead to distorted intuitive decisions about service placement (Figure 3).

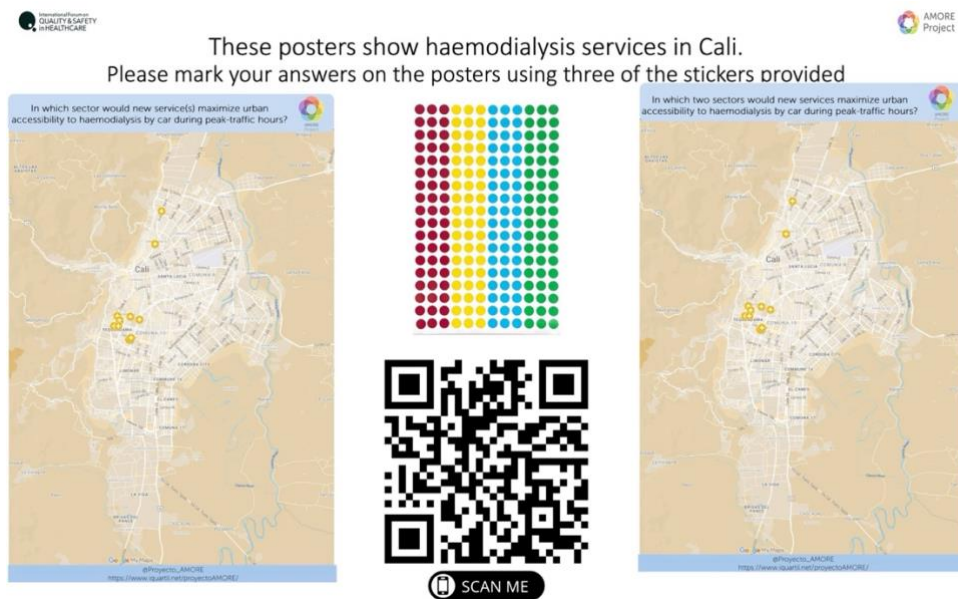


Figure 3: Instructional slide displayed at the entrance of the event, inviting participants to mark on posters where new service locations could maximise accessibility, thereby prompting reflection on travel time and population data in urban and health services planning.⁶⁵ (Open the file by clicking the image)

This thesis, developed within the Doctoral Program in Biomedical Research Methodology and Public Health, contributes to the program's mission to advance population health by applying epidemiological and knowledge translation tools and methodologies. It aims to improve health outcomes and address the needs of individuals and communities by engaging with key areas, including urban and public health, social justice, health equity, epidemiology, health systems research, implementation research, and healthcare quality.

In many metropolitan areas, traffic congestion severely delays access to essential services, particularly healthcare.^{44,66–68} These delays create structural barriers that exacerbate existing inequities and hinder progress toward achieving the Sustainable Development Goals (SDGs).^{4,17,20,44,58,67,69–71} Yet, despite its profound impact, urban and health service planning rarely addresses traffic congestion, largely due to the absence of actionable, equity-focused metrics and practical optimisation interventions.^{17,44,72}

This doctoral research developed the AMORE Project to tackle this gap by uniting civil society, public officials, and scientists to co-design and pilot an interactive, web-based tool: the AMORE platform.^{9,10,27,50,56,73,74} “AMORE” stands for Análisis espacial con Macrodatos para Orientar los Resultados en pro de la Equidad en salud — “spatial analysis with big data to guide health equity outcomes.” The name also serves as a tribute to my family, whose support and encouragement, especially after my father’s death, motivated me to pursue and complete my professional training.

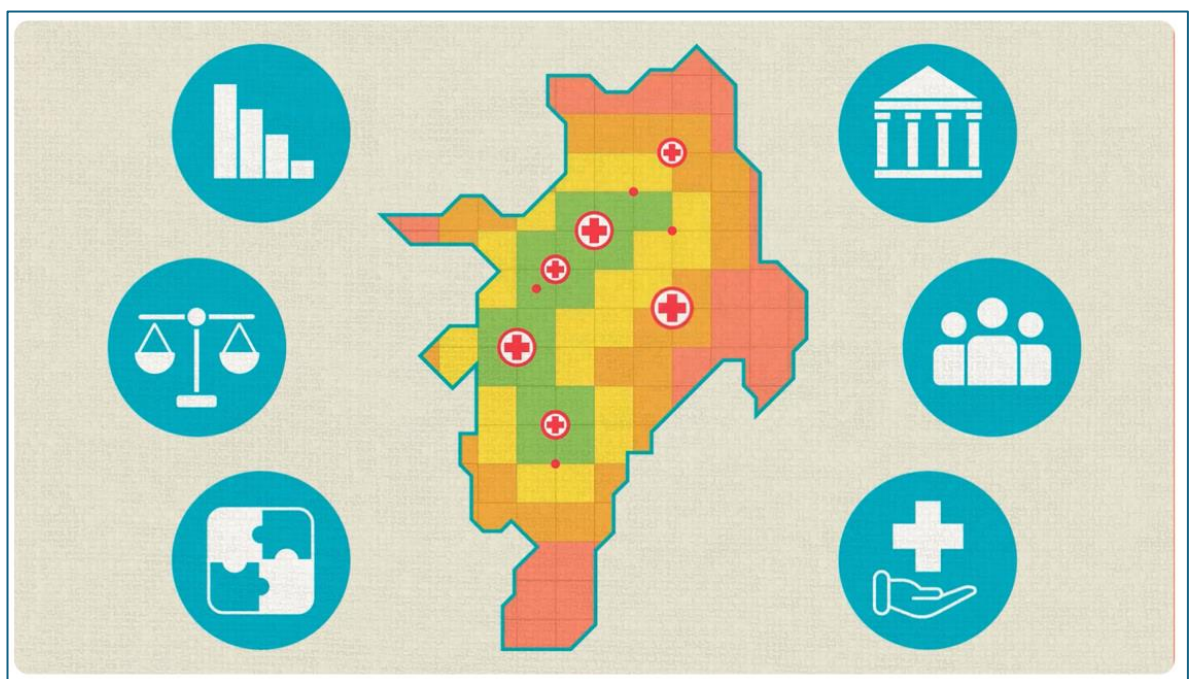
Barriers for a comprehensive approach to evidence-informed tackling of accessibility with an equity perspective include unsupported problem characterisations, failure to provide an equity perspective, lack of interest holder participation, ignoring governance structures, timeliness issues, scientific communication failures, and siloed approaches, as well as fixed assessments or prescriptive solutions to problems that require flexibility and adaptability.^{9,10,25,49,50,75–78} Key outputs include six peer-reviewed publications, including the three case-study reports underpinning this thesis’s compendium.^{3,6,79–82} We developed two sets of bilingual infographics, launched a website that hosted the AMORE Platform’s interface for each test case, and created multimedia to communicate our project and its findings. Our social media presence includes a LinkedIn page with over 1,800 followers, featuring engaging opinion leaders, policymakers, urbanists, health services planners, patient advocates, academics, and service providers.

Our multimedia collection comprises 24 open-access multimedia tutorials, informative videos, and animations, and it continues to expand. We also have 20 press releases and recordings from 20 events. Additionally, the project has generated eight preprints and has been cited in seventeen articles. During this process, the doctoral student contributed to the development of research reporting standards for equity in observational studies (STROBE-Equity), cluster, and randomised studies.^{83–89} Advocacy by interest holders has influenced local policy. Engagement is reflected in presentations and outputs produced by multiple collaborators across a wide range of sectors, knowledge users, and action groups.

Influential journals and prominent event organisers interested in this research granted publication and registration waivers and offered travel stipends. This thesis received accolades from the World Health Organization and Colombia's National Academy of Medicine of Colombia. It has also been featured and cited by leaders across diverse fields and disciplines, cities, and countries. Graduate students have developed research building on these advances, and the doctoral student and his collaborators have been invited to advise local organisations and multilateral collaborations to advance, scale up, and implement the methods and findings.^{80,90–92}

Working with knowledge users, interest holders, data scientists, and research experts led us to develop inclusive communications and shared goals. We used travel time metrics that most citizens understand and addressed a knowledge gap identified by geography, mobility, and public health experts in reviews.^{10,34,44,60,62,68,75}

1.1 A four-minute presentation of the project proposal.⁹³



Video 1: AMORE Project presentation (2020)⁹⁴ (Open the file by clicking the image)

2 Objectives

This thesis addresses a clear problem in urban health and transport policy: the lack of tested, accessible, adaptable, and policy-relevant tools to support public debate and the engagement of interest holders and the diverse sectors that shape decisions and actions influencing travel times to critical services in cities affected by traffic congestion.^{20,34,68,95–99} As a result, metrics that account for traffic congestion and incorporate an equity perspective remain underdeveloped, despite travel time being a key determinant of access to essential health services and of health equity (see the Glossary in section 9.2).^{63,64,68,100–102} Existing analytical tools are primarily designed for expert use, limiting their capacity to inform public policy processes or to enable a shared understanding of how traffic congestion shapes inequities in access.^{3,9,103,104} Moreover, many of these tools are difficult to update as urban conditions evolve. They are often prescriptive and rigid, constraining decision-makers' ability to test alternative scenarios and meaningfully compare policy options.^{3,9}

Primary objective

Develop and test a participatory approach that generates dynamic accessibility assessments, identify up to two facility locations that maximise urban accessibility in Cali, Colombia, and forecast the impact of new locations on accessibility, with an equity perspective.⁶

Specific Objectives

1. **Assess** the temporospatial characteristics of accessibility and equity for tertiary emergency care, haemodialysis, and radiotherapy services when travelling by car in urban Cali, Colombia.
2. **Produce dynamic accessibility assessments** using selected travel-time thresholds, allowing comparison across different times of day and traffic conditions.

3. **Determine** whether populations in situations of vulnerability—by socio-economic status, geographic location, or ethnicity—incur longer travel times when accessing the selected tracer services.
4. **Compare** equity-oriented accessibility patterns at two distinct moments of the COVID-19 pandemic, highlighting how changes in mobility conditions affected vulnerable populations.
5. **Quantify** the absolute and relative changes in accessibility attributable to traffic congestion.
6. **Model** the potential improvements in accessibility that could be achieved through the expansion of services and identify optimal locations for such expansion based on accessibility optimisation criteria.

The general objective of this thesis was to assess dynamic accessibility evaluations for selected healthcare services in urban Cali, Colombia, and to predict the potential improvements that could be achieved if new services were strategically introduced. We stated that we would accomplish this by engaging stakeholders, considering traffic congestion, utilising analytics and modelling, providing an equity perspective by disaggregating data, and employing sources such as big and open data to facilitate scalability and replicability.

Our specific objectives focused on examining the relationships among traffic congestion, accessibility, and equity.

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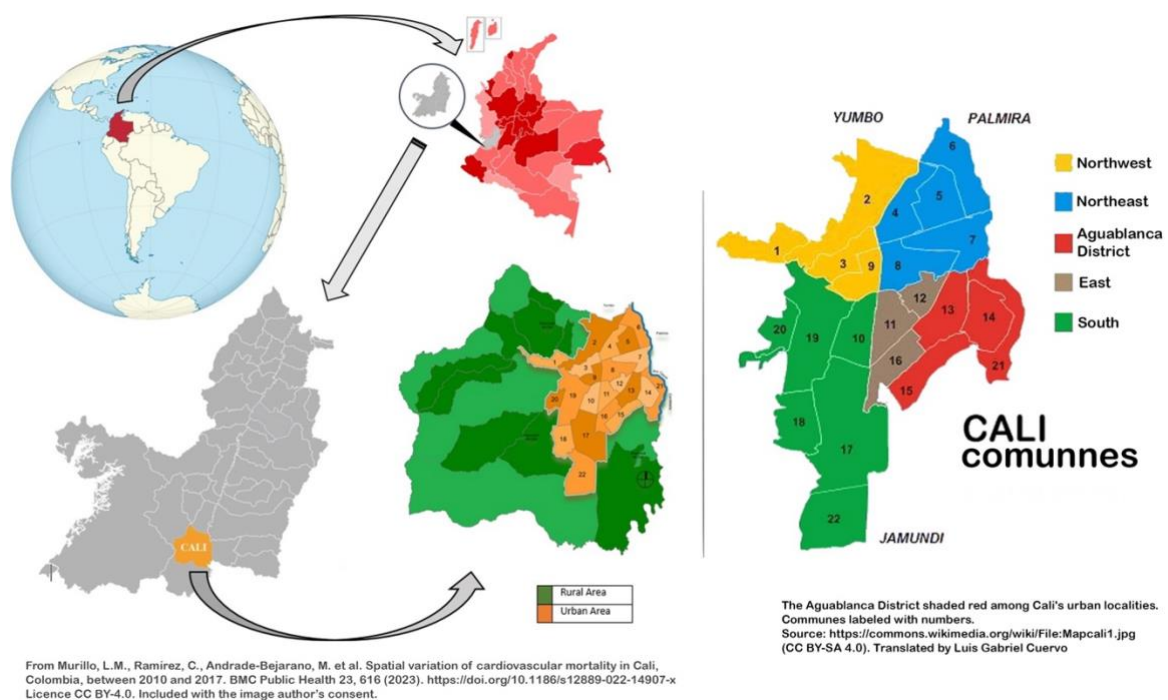
3 Methodology used in developing the doctoral work

3.1.1 Design and rationale

This thesis follows a compendium of publications format. The methodological core comprises two cross-sectional, city-wide spatial analyses of car-based travel time accessibility, complemented by scenario modelling that tests how the addition of services could improve accessibility. Methods were co-designed with knowledge users and interest holders to ensure policy relevance and transparency.

3.1.2 Setting

The setting was urban Cali, Colombia (Map 2). The tracer services studied were tertiary emergency care—where every minute counts—and ambulatory haemodialysis and radiotherapy, selected to represent frequently used services associated with high-cost chronic conditions.^{68,97,98,105–113} Together, these services capture distinct yet complementary dimensions of urban health service accessibility under conditions of traffic congestion.



Map 2: Cali's location in Colombia and the Valle del Cauca Department, and the spatial layout of the 22 communes and five districts that formed the city's urban area in 2020. Included with permission. ^{114–116}

The rationale for selecting these tracer services lies in the differing implications of prolonged travel. In tertiary emergency care, delays can be detrimental to prognosis and may lead to additional treatment needs. Radiotherapy and haemodialysis, by contrast, are critical ambulatory services that require frequent travel—often several times per week—keeping patients and carers occupied for hours.^{95,98,108,113,117,118} This entails direct, indirect, and intangible costs that can strain household economies and, in some cases, lead to catastrophic health expenditure.^{108,119–122} In Colombia, utilisation of these services is monitored through Colombia’s High Cost Account, ensuring the availability of reliable use data.^{111,123}

Cali is Colombia’s third-largest city and, in 2020, had an estimated urban population of 2.258 million residents. It is the dominant city in Colombia’s Pacific region, and its health institutions receive referrals from across this region. The city is divided into 22 communes, organised within five districts (Map 2) and is transitioning to a special district with six administrative localities.^{124–127} About half of Cali’s population lives in low-income housing, 41% in middle-income housing, and 9% in high-income housing, including resident workers (Figure 4). About 84% of the population identifies as of white descent, and 14% identify as afro-descendent, with a small proportion identifying as Indigenous or Rrom.⁶ When the population and services are mapped, the city’s socioeconomic segregation and the distribution of the studied services in low-density, wealthy areas confirm findings from descriptive studies (Map 3).^{128–130}

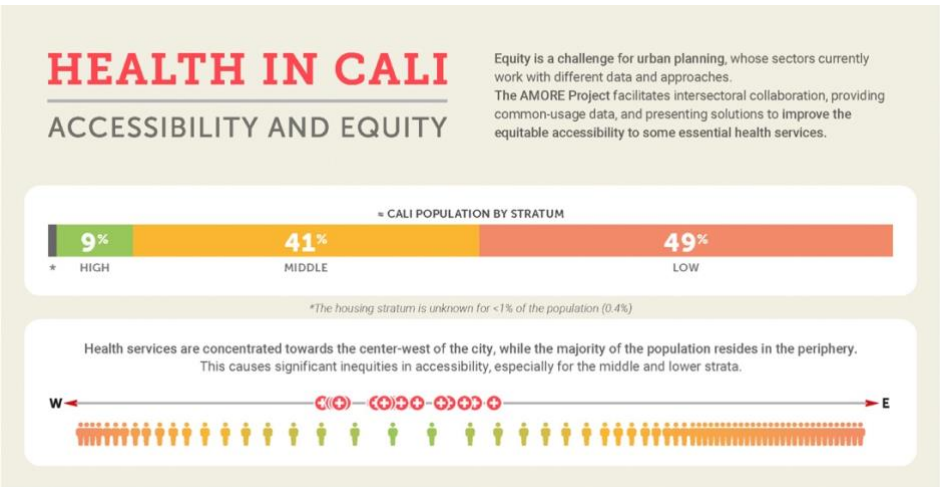


Figure 4: Distribution of Cali’s population by housing socioeconomic stratum, drawn from one of the project’s infographics. (See Figure 6)

3.1.2.1 Car-based travel as a pragmatic proxy for urban accessibility

Considering that the study had no external funding and that acquiring detailed travel-time data through commercial application programming interfaces entails substantial costs, the selection of transport modes needed to be parsimonious and analytically defensible. We relied on semi-structured interviews with key informants, including service providers, community workers, patient advocates, and service users, to identify transport modes that were both commonly used and policy relevant for accessing the selected tracer services.

Searches of Google Scholar and MEDLINE, complemented by consultations with collaborators, identified no studies in Colombia that formally assessed transport mode preferences for accessing haemodialysis, radiotherapy, or high complexity emergency care. However, convergent evidence from informant testimonies and from publications by community workers and patient advocates consistently indicated that car-based travel, referring to travel by automobile, was the predominant means of access across all three services. This typically involved the use of a private vehicle or a hired car rather than public transport. Patient advocates further noted that the COVID-19 pandemic reinforced reluctance to use public transport, particularly among haemodialysis and radiotherapy users, who were aware of their compromised immune status.^{131–135}

Ambulance services were reported to be primarily deployed for road traffic injuries and to exhibit long and unpredictable response times for other emergencies, limiting their reliability as a means of access. This assessment was corroborated by news reports and by the twenty-eight interviews completed between July 2020 and March 2022, which included local mobility and public health civil servants (Figure 5).^{6,136–138} As a result, individuals frequently relied on being driven by an acquaintance or on hiring an automobile, both in emergencies and for scheduled ambulatory care.

AMORE Platform development

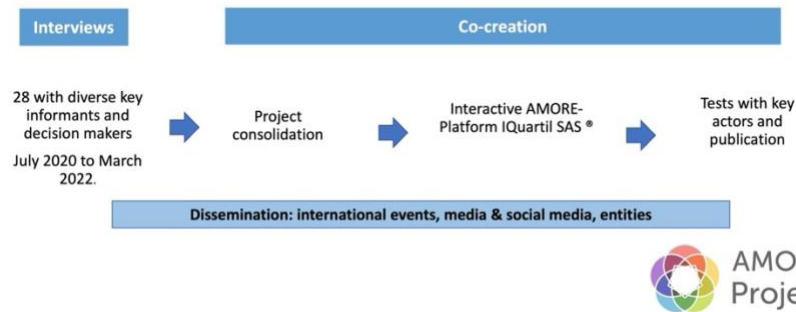
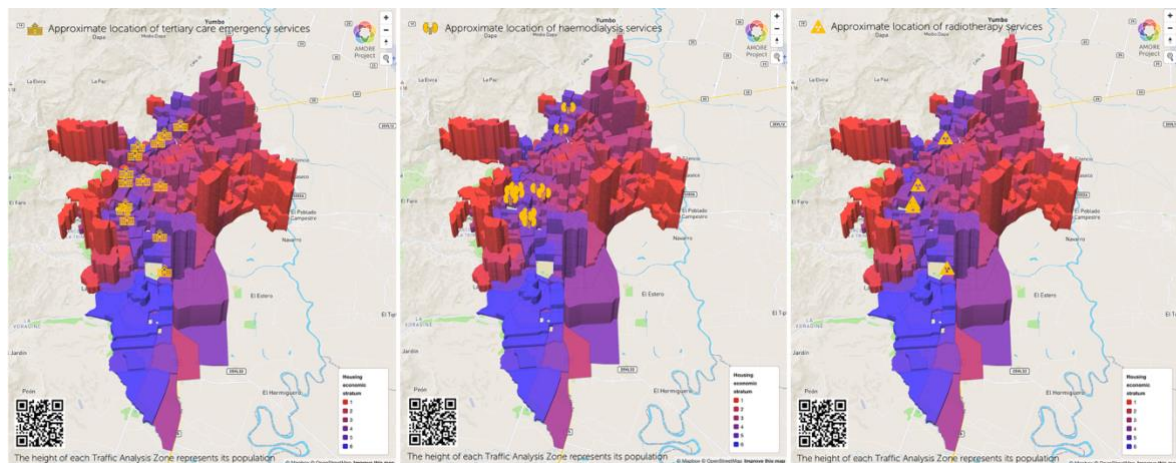


Figure 5: Description presented at the 7th Global Symposium on Health Systems Research, November 2022.¹³⁷

From an analytical standpoint, focusing on car-based travel enabled consistent estimation of travel times across the urban area, thereby facilitating comparability between neighbourhoods and across alternative service-location scenarios. While this approach does not capture the full diversity of mobility modalities, it provides a conservative and standardised basis for assessing the spatial effects of traffic congestion on access to essential services. Importantly, the use of car-based travel times does not imply normative assumptions regarding preferred modes of transport; rather, it reflects a pragmatic modelling choice grounded in observed practices and constrained by available resources. In this context, car-based travel constituted a reasonable proxy for urban accessibility for the purposes of delivering a proof of concept.^{6,131–135}



Map 3. Tracer service locations and dominant housing socioeconomic distribution (Red represents low-income and indigo high-income housing with intermediate shades for the six income levels). The height of each TAZ represents its population density.¹³⁰

The Mayor's Office of Cali is supported by fifteen secretarial bureaus, several of which are directly relevant to this study, including Mobility, Public Health, Infrastructure, and Territorial Development and Citizen Participation. In addition, the municipal administration comprises ten administrative departments, including Municipal Planning and Information and Communication Technologies. The Mayor's Office is overseen by the Municipal Council, seven members of which serve on the Planning and Land Commission. The current organisational structure is presented in Annexe 9.17.^{139–141}

3.1.3 Engaging knowledge users and consolidating the collaborative team.

This section describes how knowledge users were engaged and how the collaborative team evolved over the course of the doctoral programme. It is complemented by the annual reports submitted to the University (Annexe 9.18), which document progress, and by recordings, outputs, and timelines posted on the project's Padlet.^{13,31,33,93,142–147}

The work recognises the need to approach accessibility by embedding research within a systems perspective that extends beyond any single sector or organisation, identifies challenges, and co-designs, tests, and applies solutions and improvements with multiple actors, nodes of influence, and interest contributors.^{148,149}

Throughout the process, the doctoral work prioritised collaboration with local people and institutions and was intentionally organised to foster ownership. Members of the collaborative were supported to act as active representatives of the project and, where appropriate, to take the lead on specific activities such as interviews, presentations, and external engagement, working in coordination with the doctoral student and sharing resources. An explicit equity lens was applied throughout, and momentum was sustained with support from the full group using a range of communication tools.¹⁵⁰

The overarching strategy adopted by the doctoral student was to anticipate the types of knowledge, expertise, and perspectives required at each stage of the research and to engage them progressively, in consultation with thesis advisors and key informants. This strategy aimed to build a shared vision across sectors and interest holders; agree on indicators, data sources, and common goals; promote ownership and accountability; strengthen local knowledge and capacity; and mobilise political and citizen advocacy for evidence-informed improvements in urban and health services planning.^{10,60,62}

Beyond core disciplinary expertise in urban health and mobility, the approach explicitly incorporated service providers, user and patient networks linked to the tracer services, and individuals with lived experience, engaging actors across constitutional, operational, and collective levels of governance.^{10,12–14,60,151}

Recognising the role of urban observatories as knowledge brokers in Latin America and drawing on existing regional networks, the doctoral student also engaged with urban observatories in Bogotá and other cities, including Lima (Perú), facilitating the identification of additional collaborators and partners.^{152–154}

The collaborative group and key informants included a strong representation of individuals with deep contextual knowledge of Cali.^{79,81,82,93,147,155,156} These comprised policymakers, civil servants, service providers, patients (as service users), and academics from a wide range of disciplines, including social sciences, health

systems and services research, public health, geography, mobility, economics, programming, data science, and policy advisory fields, with many contributors based in Colombia and particularly in Cali. Their sustained engagement throughout the study was critical for assessing local evidence, interpreting its relevance within specific social and institutional contexts, and integrating local knowledge with empirical findings. This collective expertise informed judgements regarding the representativeness, accuracy, and appropriateness of the data sources and analytical outputs generated or used by the project.^{10,60,151}

The subsections below describe how this engagement strategy was operationalised over time, with particular attention to the consolidation of the collaborative team and the evolving roles of knowledge users.

3.1.3.1 First academic year – February to September 2020 (Annexe 9.18.1).

Between February and September 2020, the doctoral project focused on framing a policy-relevant research problem and testing its feasibility under constrained conditions. This shortened academic period concentrated on conceptual development, exploratory analyses, and the identification of disciplinary and intersectoral competencies required to address accessibility, traffic congestion, and equity in health services planning. Engagement was initially concentrated among thesis supervisors, public health researchers, urban mobility specialists, and data scientists, establishing a shared analytical language and confirming the viability of using open data and travel-time big data in the absence of external funding.

From the outset, the project was conceived as a co-produced endeavour, grounded in participatory research traditions and oriented toward iterative knowledge translation. Early engagement prioritised shared understanding, transparency, and reflexivity. Visualisations (graphs, maps, and slide-based materials) were used to communicate emerging ideas, and meetings were recorded with consent to support reflexive note-taking and the systematic maintenance of research logbooks. As the COVID-19 pandemic unfolded, all activities were conducted virtually.

The initial working group was intentionally assembled to combine expertise at the intersection of data science, public health, and mobility. It included senior data scientists, professors in public health and innovation, and specialists in mobility and geomatics. This group functioned as an early co-production space where feasibility, analytical decisions, and policy relevance were discussed collaboratively.

During this year, the doctoral student engaged participants through the Data Science for All challenge (see Section 3.4.2), developing early prototypes and testing the proposal in a national data-science training and challenge organised by Colombia's Ministry of Information and Communications Technologies and an international consortium. In parallel, a knowledge-translation strategy based on visual and narrative methods was initiated. Internal seminars led by Prof. Ciro Jaramillo supported collective deliberation on mobility concepts, the selection of tracer services, and their relevance to equity-oriented accessibility analysis.

Additional expertise was progressively incorporated, including social sciences, equity research, and health systems and policy research. Communication channels (including WhatsApp groups) were established for contributors and working groups. Ten meetings were held with key informants, a concept note was developed, and the first AMORE platform prototypes were tested. Informants included advisors from the Mayor's Office of Cali, the Deputy Ministry of Information and Communications Technologies, emergency response authorities of Valle del Cauca, and the municipal Secretariats of Public Health and Mobility. Follow-up working sessions supported the joint definition of research questions, identification of knowledge gaps, and appraisal of potential policy impact.

A university-managed cloud environment was used for shared storage and version control. Tracer services were agreed upon, census data were adjusted to 2020, and official georeferenced datasets for health services and Transport Analysis Zones were compiled. Descriptive, diagnostic, and predictive modelling strategies were

collectively agreed upon, culminating in the drafting of the project protocol. By the end of this period, the foundations for sustained co-production, visual knowledge translation, and policy-relevant analysis were firmly established.

3.1.3.2 Second academic year – October 2020 to September 2021 (Annexe 9.18.2).

During the second academic year, the project moved from conceptual framing to formalisation and early validation. A multidisciplinary protocol was co-developed and refined with collaborators from public health, epidemiology, urban planning, mobility analysis, and integrated knowledge translation.¹⁵⁷ This process clarified tracer services, equity-relevant indicators, and analytic strategies, and resulted in a peer-reviewed protocol publication, marking the project's first major scientific milestone.

Engagement expanded beyond academia to include urban observatories and civic organisations, reinforcing the importance of transparency, usability, and interpretability. Early dissemination occurred through seminars and invited talks spanning health systems research, urban studies, and public policy, functioning as validation checkpoints rather than dissemination endpoints.

Operationally, contributors compiled and curated approximately 800 references, developed new prototypes for situational analyses and predictive modelling, and identified one or two locations optimised for accessibility. The platform identified traffic-congestion clusters and linked congestion levels to travel times, producing disaggregated, equity-focused visualisations (choropleth maps and infographics). This year, 27 targeted training sessions were delivered; the collaborative group grew to 8 active members; and a LinkedIn page was launched to communicate with peers, experts, and collaborators.

3.1.3.3 Third academic year – October 2021 to September 2022 (Annexe 9.18.3).

In 2021–2022, the project entered a phase of substantive operational development. Data collection was completed, and the AMORE platform was developed and iteratively tested, enabling dynamic situational and predictive analyses. Key milestones included the publication of the approved protocol following ethical review, the release of the first empirical publications, and the establishment of a functional, interactive platform.^{3,6,158}

Dissemination expanded across disciplinary forums in public health, health services research and planning, urban mobility, and data science, providing cross-sector validation. The number of contributors increased to more than two dozen, with more than forty key informants, including service providers, patient advocates, analysts, and civic actors. Engagement extended to urban observatories in Colombia and Peru, equity networks, and doctoral groups focused on sustainable urbanism. A collaboration was also initiated with an international project coordinated by Universidad del Valle addressing mobility in low-income and peripheral neighbourhoods of Cali.

The shared Zotero library expanded to 1,446 references, and collaborators contributed multimedia guidance to support the interpretation and reuse of the platform outputs. The University responded to a cyberattack it suffered in 2021, establishing a new work environment with Office 365, losing files stored in the Google ecosystem that was hacked.^{159,160}

3.1.3.4 Fourth academic year – October 2022 to September 2023 (Annexe 9.18.4).

The 2022–2023 period marked a transition from scientific credibility to broader external validation and influence. The project was presented—by invitation and competitive selection—at national and international forums spanning global health, urban planning, mobility, demography, public policy, and health systems research. Participation in the World Health Organization’s LEAD Innovation Challenge functioned as a structured validation process, leading to methodological refinement

and expanded engagement with Colombian and regional experts advising policy processes.

Collaboration expanded to 36 contributors, including urban observatories, doctoral networks, demographers, public policy schools, civil society organisations (e.g. City Cancer Challenge), regional transport and accessibility networks, patient organisations, and representatives linked to each tracer service. Operational outputs expanded substantially, including new multimedia products, four additional infographics, and sustained growth in social media engagement. The project's LinkedIn community reached approximately 600 followers. Published articles accrued more than 8,400 downloads. The project was featured in press releases and presented at prominent international events across Chile, Colombia, Denmark, Mexico, Spain, Switzerland, the United Kingdom, and the United States.

3.1.3.5 Fifth academic year – October 2023 to September 2024 (Annexe 9.18.5)

During 2023–2024, the project demonstrated clear indicators of uptake and influence. Three peer-reviewed articles were published, two in first-quartile journals (both designated Editor's Choice), with high download and citation rates. The methodology began to be emulated and adapted by external research groups, indicating transferability beyond the original context.^{79–81}

Strategic partnerships were consolidated with civic organisations, urban observatories, and service-delivery initiatives, supporting application of findings in municipal debates and accountability processes. The collaborative network expanded to approximately fifty contributors, many of whom independently presented the work in sector-specific forums. Social-media engagement and use of the Padlet-based repository continued to grow, reinforcing visibility and shared ownership. Importantly, findings were cited in Cali's 2024–2027 Development Plan and in the academic evidence informing the city's Land Use Plan. Publications had accrued more than 20,000 downloads and over a dozen citations across diverse

disciplines. Findings were also presented at a regional emergency preparedness and response panel in Quito.

3.1.3.6 Sixth academic year – October 2024 to September 2025 (Annexe 9.18.6)

The final academic period focused on consolidation and synthesis. The requirements for thesis submission as a compendium of publications were met, and the research line was explicitly articulated as implementation-oriented. Engagement extended to intergovernmental organisations and development partners, positioning the methodology within regional discussions on urban health monitoring and equity.

By this stage, the collaborative group functioned as a distributed community of practice, with contributors independently applying, adapting, and teaching the approach. Indicators of maturity included sustained growth in collaborators (≈ 50), social media followers ($>2,200$), article downloads ($>25,200$), and citations (>30). The Zotero virtual library hosts about 2,800 references. The project's methodology was discussed in policy dialogues and case studies and recognised by international institutions. A joint working group and agreement between the Inter-American Development Bank and the Pan American Health Organization were established to advance accessibility metrics that account for traffic congestion and to create a regional open-data clearinghouse. We are aware of three graduate students who developed their theses by building on the AMORE project. A highlight was returning results to interest holders in Cali through a public event organised by Universidad del Valle, accompanied by national media coverage. The doctoral student received an award for excellence in innovation from the WHO Director.

3.1.3.7 Summary

Across the doctoral trajectory, operational development and intersectoral collaboration evolved in tandem. Early conceptual alignment enabled methodological coherence; subsequent co-development of tools and publications built scientific legitimacy; and sustained engagement across disciplines and sectors

fostered ownership, validation, and policy uptake. Quantitative indicators—growth in publications, collaborators, events, and communities of practice—mirror qualitative shifts in how the project was used: from exploratory research to a shared decision-support resource. This progression demonstrates that intersectoral, people-centred research can achieve influence and change when collaboration is treated as a core methodological component rather than an adjunct to dissemination.

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Table 1: Chronological summary of the doctoral project

Academic year	Focus and strategic purpose	Key operational developments	Outputs and indicators of achievement	Collaboration, reach, and validation
2020 (Feb–Sep)	Problem framing and feasibility under constraints	Definition of research questions; identification of tracer services; exploratory analyses using open data; alignment with supervisors and core experts	Preparatory analyses and concept notes; no formal publications	Small core team (supervisors, data science, public health, urban mobility); early consultations with civic and urban observatory actors
2020–2021	Formalisation and early validation	Co-development of multidisciplinary protocol; refinement of indicators and methods; ethics and institutional alignment	Draft protocol preprint; early seminars and invited talks.	Growing multidisciplinary group; engagement with urban observatories and civic actors; early cross-sector validation
2021–2022	Execution and scientific credibility	Completion of data collection; development and testing of the AMORE platform; first full analyses	Editorial (Q3); original research article (Q1); preprints; initial open datasets. Peer reviewed protocol published (Q1) with ethics approvals	Expanded collaboration including service providers and patient advocates; presentations in public health, health services research, urban mobility, and data science forums
2022–2023	External validation and intersectoral scaling	Iterative platform refinement; predictive and prescriptive analyses; systematic open science practices	Multiple preprints; datasets in Open Science Framework; >70 explanatory videos; interactive dashboards; BMJ Open results.	~36 contributors; participation by invitation and competition in global health, urban planning, mobility, demography, and policy forums; WHO LEAD Innovation Challenge finalist
2023–2024	Adoption, replication, and policy anchoring	Consolidation of partnerships; application of findings in municipal and civic processes	Two Q1 publications plus contributions to Q1 published reporting guidelines on equity in observational research, platform appraisal, and two master's thesis; high download and citation rates; interactive web interfaces publicly available.	~50 collaborators; emulation in other countries; growth of social media and Padlet communities; inputs to Cali 2024–2027 Development Plan
2024–2025	Synthesis and implementation readiness	Thesis by compendium finalised; articulation of research line; engagement with intergovernmental actors	Compendium of Q1 publications and thesis submitted for review; policy-relevant syntheses; continued cross-disciplinary citations	Mature community of practice; independent use and teaching of the approach by collaborators; recognition by PAHO/WHO and development partners

3.1.4 Units of analysis

The units of analysis for journey origins were the Traffic Analysis Zones (TAZs) in which residences were located, measured from the population-weighted centroid of each residential TAZ. For tertiary emergency care, destinations were defined by the service entrance coordinates. For ambulatory haemodialysis and radiotherapy, destinations were represented by the population-weighted centroid of the TAZs hosting these services.

With a population of 2.26 million, Cali is a tropical city in southwestern Colombia, located near the equator. It lies in a seismically active region between the Cauca River to the west and the Western Andean Mountain Range to the east, which separates it from the Pacific coast. The Cali River crosses the northern part of the city, shaping both its landscape and infrastructure. The surrounding valley supports extensive agricultural activity, particularly sugarcane plantations, which underpin the regional economy and influence land use, labour markets, and environmental health. Beyond its agricultural base, Cali functions as an industrial and cultural hub. These geographic and socioeconomic conditions shape urban development, transportation planning, and exposure to environmental risks, all of which are highly relevant to studies of health accessibility and equity. Taken together, these features made Cali an appropriate and strategic choice as the case study city for this thesis.

As the principal city of Colombia's Pacific region, Cali serves as the leading centre for public health, higher education, and regional governance. Strategically located, it connects the country's southern Andean region with other Andean conurbations, while also linking the Pacific trade routes with the Atlantic. Urban expansion has followed a predominantly elongated north–south axis, contributing to the main corridor linking the Pacific region and coast to the country's interior. This spatial configuration generates both challenges and opportunities for the analysis of transportation flows, health service accessibility, and spatial equity.

Cali is also home to the main campus of Universidad del Valle, one of Colombia's most influential public universities. Frequently consulted by decision-makers at the local, regional, and national levels, it provides a strong multidisciplinary platform with recognised expertise in public health, engineering, and policy. Its alumni, faculty, and students actively contribute to public initiatives and policy development. University leadership has expressed interest in this project, particularly in advancing geospatial accessibility studies and travel time assessments. A recent static baseline assessment of healthcare accessibility offers a valuable point of contrast with the dynamic approach developed in this thesis.¹⁶¹

Although research at the intersection of health systems, policy, and urbanism is growing, contextual factors remain decisive. The economic factors shaping policy decisions vary significantly across municipalities, underscoring the need for methods that enable comparability across settings. Approaches that standardise accessibility assessments enable benchmarking, monitoring, and continuous improvement, while also deepening understanding of their societal impacts. In this regard, the data collected for Cali not only informs local policy but also helps identify knowledge gaps, strengthen monitoring frameworks, and define future research priorities. Importantly, the data infrastructure and methods available for Cali are also applicable to other Colombian cities with traffic congestion, as well as to many cities across Latin America and worldwide (see Annexe 9.10), thereby reinforcing the multicentric relevance of this work. Accordingly, this thesis presents lessons learned and recommendations to support local and multicenter studies aimed at improving health access and equity.

3.1.5 Data sources.⁶

- Population and housing: 2018 census microdata (DANE), with a documented adjustment to approximate 2020 conditions.
- Health services: official registries and validated facility geolocations for the three tracer services, obtained from the National Special Registry of Health

Services Providers (REPS), the initials in Spanish. It included fourteen tertiary care emergency services (code 501 plus high complexity), eleven haemodialysis services (code 733), and five radiotherapy services (code 711).

- Geographic boundaries for traffic analysis zones (TAZs) from the 2015 IDESC portal, plus complementary sector boundaries to complete coverage.
- Road network and congestion: dynamic travel time estimates obtained from Google Distance Matrix application programming interface (API) for two time windows in 2020, July 6 to 12, and November 23 to 29.

3.1.5.1 Bibliographic collection

Throughout the project, we sought to remain abreast of relevant developments building on the expertise of the research team, without undertaking a formal systematic review. The principal researcher and project coordinators invited members of the multidisciplinary team to contribute key publications from their respective fields and to submit relevant references. These were organised and curated in a shared virtual Zotero library (see footnote 2)².

Purposeful literature searches were conducted during the first half of 2020, while the study protocol was under development. These included searches of the Web of Science Core Collection, Google Scholar, PubMed, LILACS, Epistemonikos, EvidenceAid, and the McMaster Health Forum's Health Systems Evidence, as documented in one of our reports.⁸¹ Database alerts were subsequently established to monitor emerging publications. Although a systematic review was initially considered and a protocol was registered, this workstream was not completed, as doing so would have compromised the timely completion of the broader project.⁹²

The bibliographic collection continued to expand throughout the project and encompassed a wide range of sources, including literature reviews (integrative, meta

² Project's collaborative Zotero collection.

https://www.zotero.org/groups/2499307/mapas_din%C3%A1micos_y_acceso_equitativo_en_salud/library

narrative, realist, systematic, overview, and scoping reviews; see Annex 9.12), policy and normative frameworks, individual empirical studies, preprints, and other relevant materials.^{162–164} Initial references were identified through keyword searches developed for a scoping review. However, these records were lost following a prolonged ransomware cyberattack that compromised the University's Google Suite accounts, including Google Drive and email services.^{165,166}

Additional references were incorporated through expert exchanges, hand searching, key informant input, and materials shared via social media, particularly through the project's LinkedIn page, which has attracted over 2,200 contacts. This approach also enabled the identification and screening of relevant materials emerging from the events, networks, listservs, and subscriptions accessed by the diverse group of authors and collaborators involved in the project. The search strategy was later reconstructed as faithfully as possible and published in our report on haemodialysis and in a related review protocol.^{81,167} Ongoing surveillance enabled us to identify systematic reviews and overviews on health services accessibility,³ both general and tracer service-specific, including several relevant publications published as late as 2025.^{20,34,44,58,64,67,69,168}

From this corpus, we identified literature reviews relevant to our research focus (Annex 8.11), including studies addressing dynamic accessibility, traffic congestion, and the use of open and big data, and, in some cases, equity considerations. Most of these reviews were conducted by highly specialised and relatively homogeneous teams, typically drawn from geography, engineering, or public health. None, however, incorporated a participatory approach or presented findings in formats readily interpretable and actionable for interest holders such as civic leaders or patient representatives. These studies predominantly relied on static accessibility assessments with fixed parameters, often highlighting problems without offering interactive tools to explore scenarios or identify solutions.^{3,6,9,14,29,55,56}

³ Zotero virtual collection of topic reviews

https://www.zotero.org/groups/2499307/mapas_din%C3%A1micos_y_acceso_equitativo_en_salud/collections/9MZ9T43I/collection

In contrast, our project pursued a broader, explicitly people-centred objective, engaging a diverse group of knowledge users and other interest holders to test a novel approach to leveraging open and big data to examine the relationships among accessibility, traffic congestion, and equity.^{4,5,18,76,169–172} These relationships were understood to intersect with broader concerns regarding poverty, equity, human rights, and health.^{44,68,75,102,173–177}

3.1.6 *Variables and derived measures.*^{6,82}

- **Primary outcome:** travel time by car (minutes) from residential TAZs to the nearest eligible service. Travel times are intuitively frequently used and understood by people planning their travel in busy cities.
- **Derived indicators:** proportion of population and population within pre-specified travel time thresholds for a specific traffic congestion level, a measurement of cumulative dynamic accessibility; absolute and relative changes in accessibility from free-flow to congested conditions; between-group differences across equity stratifiers. Cumulative accessibility opportunities were calculated as the proportion of the population within specified travel-time thresholds for defined congestion levels.^{178,179}
- **Equity stratifiers from the census:** residential socioeconomic stratum (1–6), TAZ or city sector when a TAZ is unavailable, and available sociodemographic markers (e.g., self-identified sex, ethnicity, civil status, health status, education-level proxies, where applicable).

3.1.7 *Analysis methods*

- **Dynamic accessibility:** compute travel times per origin–destination pair for each of the nine traffic congestion clusters, for each day and hour of the two weeks assessed in 2020; summarise sectors, families, houses, and people covered for the selected travel time thresholds. For emergency services, we

arbitrarily selected fifteen minutes, and for ambulatory high-cost conditions, twenty minutes.

- **Scenario modelling and optimisation:** identify the **one** and **two** candidate locations (TAZs) where new services would maximise city-wide accessibility (population within threshold) and estimate gains relative to the status quo.
- **Equity analysis:** compare indicators across stratifiers and quantify gaps between groups and sectors.
- **Graphic representation:** in choropleth maps, city maps showing existing and proposed service additions, descriptive graphs and charts for absolute and proportional numbers. Colours and designs were selected with science communication experts and key informants.

3.1.8 Quality assurance, reproducibility, and sensitivity

- **Geocoding Quality Assurance:** coordinates for each service were verified, and errors, such as a transcription typo, were corrected.
- **Replicability:** Results from the API queries used to download travel-time big data were published and stored on OSF.io to facilitate replication. An epidemiology master's student used these for her capstone.
- **Sensitivity checks:** are possible by changing parameters, like travel time thresholds, in the web-based interactive AMORE Platform. Platform results were found to be sound and show consistent variations in the direction and magnitude of change. The platform allows for comparison of findings from using the unadjusted vs adjusted census denominators.

3.1.9 Ethics and data protection.⁶

The protocol received ethics clearance from Universitat Autònoma de Barcelona (CEEAH-6100, 16–20 Sep 2022) and Universidad del Valle (CEIFI 010-2022, 25 Jul 2022). Analyses use aggregated, non-identifiable data and comply with institutional and national standards.

3.2 Reflexivity statement

In accordance with current guidance on reflexivity in health research, reflexive practice was treated as an ongoing, structured element of this doctoral work rather than as a one-off retrospective task. The doctoral student's positionality as a public health physician and health systems researcher, with longstanding involvement in international health and research, knowledge translation, research quality, equity, community engagement, participatory research, and integrative approaches to health challenges, influenced the formulation of research questions, choice of methods, and emphasis on policy relevance and implementation.

The study was conducted in close collaboration with local institutions and actors in Cali, Colombia, as well as with local and international interest groups—including knowledge users. This proximity facilitated access to relevant data, planning processes, and valuable contextual knowledge for analysing geographic accessibility amidst traffic congestion. At the same time, it required ongoing reflexive attention to how institutional priorities, professional relationships, and considerations of policy feasibility could shape the study design, analysis, and interpretation. To support this, analytical decisions, assumptions, and trade-offs were openly discussed with the collaborative group and academic advisors throughout the research process.

The doctoral student's prior experience working in low- and middle-income settings, particularly in Cali and Colombia's Pacific region, helped identify contextually suitable policy and implementation options and facilitated mobilisation of local expertise. The student had made significant contributions to the coordination and support of health research standards and policies at the global, regional, and national levels. Involvement in initiatives focused on defining, assessing, and strengthening research ecosystems, including equity-related reporting standards, shaped the analytical approach of this study.

Equity considerations guided the identification of target populations, selection of tracer services, and choice of spatial and socio-demographic stratifiers. Engaging with knowledge users and other interest holders enhanced contextual validity and

supported knowledge dissemination and appropriation. Reflexive monitoring of this engagement helped reduce risks such as selective framing of inequities, alignment with narrow analytical frameworks or dominant policy agendas, and over-technicalisation, which could diminish the relevance of findings for public policy and plural interest-holder dialogue. Whenever possible, analytical strategies were predefined, and conclusions were validated through multidisciplinary review and iterative analysis feedback.

The researcher's dual role as analyst and facilitator of dialogue across various governance levels, including academic, policy, health providers, and users, is recognised as a potential influence on interpretation and knowledge translation. This was addressed by transparent reporting of analytical steps, uncertainties, and limitations, allowing readers and decision-makers to assess the credibility, robustness, and transferability of findings to other urban settings. The collaborative group comprised individuals from a wide range of disciplines, professions, and personal backgrounds. Beyond formal roles, many contributors relied on direct experiences with health services and urban mobility systems, enriching interpretation and grounding the analysis in real-world conditions.

Annexe 9.15 provides further detail on relevant experience gained throughout the research process, and summarises the doctoral student's trajectory, with references to his professional profile and selected research outputs.

3.3 Methods by publication (compendium)

The three studies listed here constitute a compendium of publications, published in high-impact, top-quartile journals, supported by accompanying documents that provide the necessary background and methodological approach.

3.3.1 Study 1 – Tertiary emergency care (BMJ Open, 2022)

Cuervo LG, Martínez-Herrera E, Osorio L, Hatcher-Roberts J, Cuervo D, Bula MO, Pinilla LF, Piquero F, and Jaramillo C. **“Dynamic Accessibility by Car to Tertiary Care Emergency Services in Cali, Colombia, in 2020: Cross-Sectional Equity**

Analyses Using Travel-Time Big Data from a Google API.” BMJ Open 12, no. 9 (September 1, 2022): e062178. <https://doi.org/10.1136/bmjopen-2022-062178>.

Design: Cross-sectional, city-wide analysis of dynamic travel times to tertiary emergency care for two 2020 weeks, considering traffic levels from free flow to peak traffic windows.

Data and measures: Residential TAZ origins to tertiary emergency facilities; outcome is travelling time (minutes); indicators include cumulative population within the fifteen-minute threshold; equity comparisons by socioeconomic stratum, sector, and other available stratifiers.

Analysis: Compute dynamic travel times from API; summarise indicators by traffic context and equity strata; estimate absolute and relative losses under congestion.

Summary: The study quantified the extent to which traffic congestion reduces accessibility to tertiary emergency care and widens gaps between sectors and socioeconomic and demographic groups. The study quantified the impact of traffic congestion on travel times from the place of residence, by car, to the tertiary care emergency service with the shortest travel time. It showed that specific vulnerable populations are likely to face longer journeys, raising social justice concerns. Findings point at the pertinence of considering equity and congestion in assessing accessibility.

3.3.2 Study 2 – Haemodialysis (The Lancet Regional Health – Americas, 2024)

Cuervo LG, Villamizar CJ, Osorio L, Ospina MB, Cuervo DE, Cuervo D, Bula MO, Zapata P, Owens NJ, Hatcher-Roberts J, Martin EA, Piquero F, Pinilla LF, Martínez-Herrera E, Jaramillo C, on behalf of the AMORE Project Collaboration. “**Dynamic Measurements of Geographical Accessibility Considering Traffic Congestion Using Open Data: A Cross-Sectional Assessment for Haemodialysis Services in Cali, Colombia.**” *The Lancet Regional Health - Americas* 34 (June 1, 2024): 100752. <https://doi.org/10.1016/j.lana.2024.100752>

Design: Cross-sectional, city-wide analysis of dynamic travel times to haemodialysis services during two 2020 weeks, considering traffic levels from free flow to peak traffic windows. Scenario modelling for the one and two-TAZ areas where new services would maximise urban accessibility to haemodialysis services.

Data and measures: Residential TAZ population weighted centroids to the population weighted centroids of TAZs hosting haemodialysis services; catchment area and population coverage within the twenty-minute thresholds; equity disaggregation as above.

Analysis: Contrast measurements with traffic congestion levels. Compare free-flow vs peak traffic; run optimisation to find candidate TAZs for new services; estimate city-wide and equity-specific gains.

Summary: Congestion markedly amplified geographic, socioeconomic, and ethnic inequities by lengthening travel times for frequent-use dialysis care, with the greatest penalties in densely populated eastern and peripheral areas. Locating facilities in one or two optimal TAZs substantially improved accessibility and reduced disparities. The study includes testimonies from interest holders.

3.3.3 Study 3 – Radiotherapy (International Journal for Equity in Health, 2024)

Cuervo LG, Villamizar CJ, Cuervo D, Zapata P, Ospina MB, Valencia SM, Polo A, Suárez A, Bula MO, Miranda J, Millán G, Cuervo DE, Owens NJ, Piquero F, Hatcher-Roberts J, Paredes GD, Navarro MF, Minotta IL, Palta C, Martínez-Herrera E, Jaramillo C, on behalf of the AMORE Project Collaboration. “**Improving Accessibility to Radiotherapy Services in Cali, Colombia: Cross-sectional Equity Analyses Using Open Data and Big Data Travel Times from 2020.**”

International Journal for Equity in Health. 23, 161 (2024).

<https://doi.org/10.1186/s12939-024-02211-6> Video-abstract:

<https://youtu.be/8lC1JqywAwk>

Design: Cross-sectional, dynamic accessibility assessment for radiotherapy at two 2020 weeks, representing distinct traffic conditions, plus scenario modelling for the

one and two TAZ where new services would maximise urban accessibility to radiotherapy services.

Data and measures: Residential TAZ origins and service TAZ destinations, in both cases from the population-weighted centroid; outcome travel time; coverage within twenty-minute thresholds; equity stratification by housing socioeconomic stratum, sociodemographic characteristics of the population, and sector.

Analysis: Contrast measurements with traffic congestion levels. Compare free-flow vs peak traffic; run optimisation to find candidate TAZs for new services; estimate city-wide and equity-specific gains.

Summary: Radiotherapy services are scarce and predominantly located in affluent, low-population-density areas. Consequently, traffic congestion exacerbates structurally unequal access by disproportionately increasing travel times for peripheral and low-income populations. Congestion substantially lengthened travel times to radiotherapy services, with the greatest penalties observed in densely populated eastern and peripheral areas. Modelling the placement of one or two additional facilities in optimally selected traffic analysis zones markedly improved accessibility and reduced inequities. The study also incorporates testimonies from interest holders.

3.3.4 Related frameworks

The AMORE project builds on multiple conceptual and political frameworks, including people-centred healthcare, research for health, integrated knowledge translation, the social determinants of health, health equity, social justice, and the UN Agenda 2030 with its Sustainable Development Goals.^{9,23–27,29,30,37,53,56,73,74,83,162,174,175,180–200} The “*research for health*” concept, coined at the Bamako Ministerial Forum, puts an emphasis on considering contributions from different fields of knowledge and disciplines to improve health and address problems in an integral manner. It was a shift from health research done in isolation from other sectors and fields of knowledge, and this paradigm shift was promoted by global and regional research

policies agreed by WHO member states, including every State in the Americas.^{180,183,201–203} The project exemplifies research for health by generating actionable evidence explicitly designed to inform decision-making that impacts health. Rather than producing knowledge for its own sake, the study aligns methodological innovation, data integration, and modelling with concrete policy questions faced by local authorities, urban and health planners, and service providers.

The project operationalises people-centred healthcare by shifting the analytical focus from service availability alone to the lived experience of accessing care. By measuring real travel times under congestion and incorporating testimonies from interest holders, the project foregrounds how health systems function from the perspective of patients and carers, particularly those requiring frequent ambulatory care for prolonged periods of time, or time-sensitive services such as emergency care.^{14,23,25,27}

The project adopts an integrated knowledge translation approach by looking integrally at the problem with the continuous involvement of interest holders, including policymakers, planners, clinicians, patients, and civil society actors, throughout the research process. Knowledge is co-produced, iteratively interpreted, and translated into tools, visualisations, and policy-relevant scenarios, ensuring relevance, usability, and uptake.^{29,181,184,204,205}

Mobility, spatial segregation, and urban form are treated as structural social determinants of health within AMORE's analytical framework. By demonstrating how traffic congestion interacts with residential patterns and service location, the project makes visible how non-health-sector decisions systematically shape access to essential care.^{40,44,206}

Equity is a central analytical lens of the AMORE Project. Accessibility metrics are stratified by geography, socio-economic conditions, and population density, allowing

the identification of systematic and avoidable disparities. The project moves beyond average effects to examine who benefits, who is disadvantaged, and under which conditions. The project was also an opportunity to apply current and developing health equity-reporting recommendations.^{30,53,84,85,88,207,208}

This thesis is grounded on a social justice perspective by exposing how existing urban and health system configurations disproportionately burden already disadvantaged populations. By modelling alternative facility locations and policy scenarios, it supports redistributive actions aimed at reducing unjust and preventable inequalities in access to essential services.^{37,53,77}

This thesis project supports the implementation of the UN Agenda 2030 and its Sustainable Development Goals, particularly SDG 3 (Good Health and Well-being), SDG 10 (Reduced Inequalities), SDG 11 (Sustainable Cities and Communities), and SDG 17 (Partnerships for the Goals). By linking urban mobility, health systems performance, and equity-oriented policy action, the project provides an applied, local pathway for advancing these global commitments.^{7,37,207,209,210}

In preparation for these publications, we presented the idea through various media, including an editorial and research protocols.^{3,6,93,94,147,157}

Throughout this project, under my leadership, we maintained parallel streams of work to communicate with relevant audiences, engage interest-holders across sectors, generate and discuss evidence highlighting key contextual issues, identify and present actionable solutions, validate findings, and promote knowledge uptake while considering political options to shape urban and health services planning at different levels of governance.^{9,10,25,50,51,54,209,211–216}

3.4 *What this study adds*

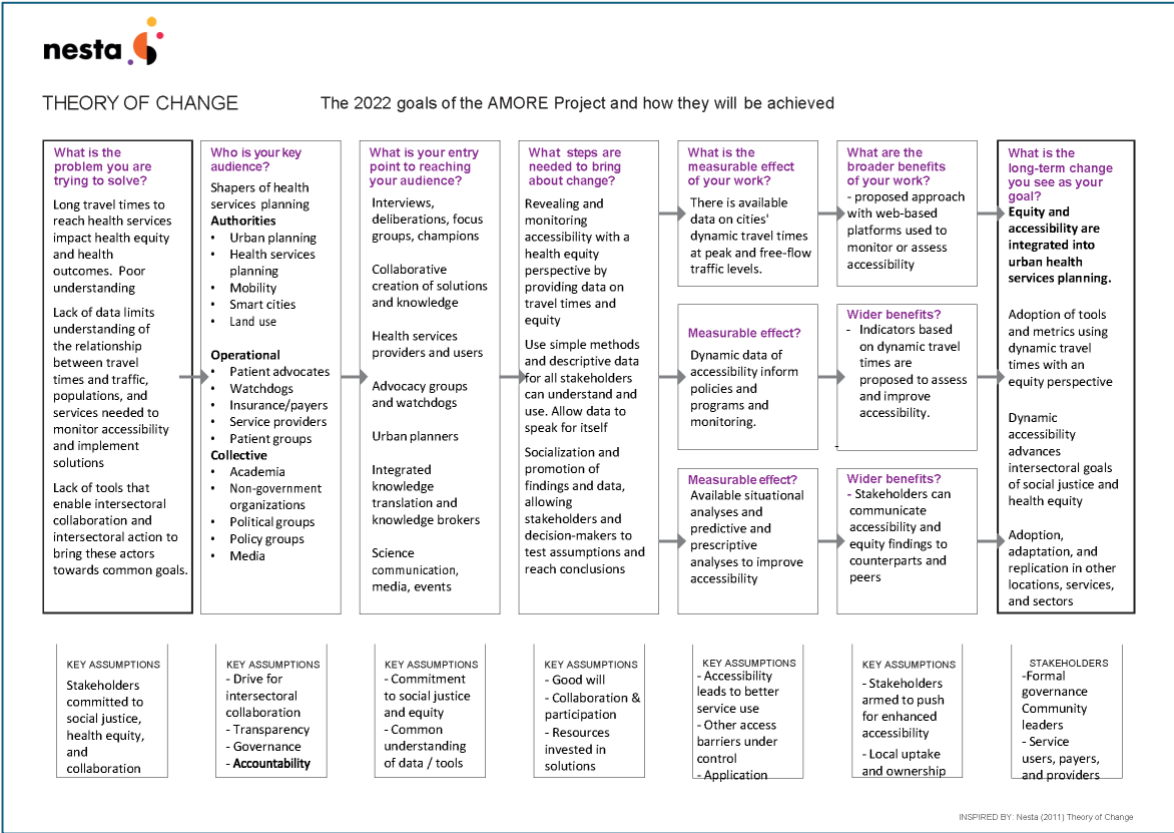
This study makes several key contributions:

- Provides novel, policy-relevant data by integrating open and big data sources with geospatial analyses, generating dynamic accessibility indicators with an explicit equity focus.
- Contributed directly to the formulation of Cali's 2024–2027 Development Plan and land-use policy, while offering a replicable methodological framework and practical digital tools that can be adapted to other cities.
- It demonstrates that citywide estimations of travel times, accounting for traffic congestion, are technically and economically feasible.
- Introduces a participatory, people-centred approach for assessing accessibility to critical health services, actively engaging knowledge users and other interest-holders throughout the process. Collaborators participated at every stage of the project, from its conceptualisation, the development of communication tools and the platform, obtaining testimonies and insights from interest holders, reporting results and representing the study in diverse scenarios, and advocating for implementation and social appropriation of knowledge.
- Demonstrates an effective and organic knowledge translation pathway to policy, linking academic research with urban and health planning agendas. This work was volunteer, did not require external funding, and has resulted in the project's continuity and engagement with related initiatives with local partners.
- Quantifies the impact of traffic congestion on access to hemodialysis, radiotherapy, and tertiary emergency care, highlighting disproportionate effects on vulnerable sociodemographic groups.

These contributions were the result of deliberate design. A theory of change was developed by the principal investigator, with inputs from initial collaborators and agreed upon by the collaborative project contributors. It provided the conceptual framework guiding the project, including the selection of additional collaborators and the refinement of the doctoral thesis protocol. ⁶ The revised protocol was reviewed and approved by the Institutional Review Board of the Universitat Autònoma de

Barcelona and by the Ethics Review Committee of the Universidad del Valle in Cali, Colombia, ensuring compliance with international academic standards, national legislation, and local ethical requirements.

With the Theory of Change guiding the project (see Publication 1), the selection of networks, sectors, and interest-holders was structured to ensure representation across governance levels. Following Abimbola’s multi-level framework for analysing primary health care governance, the project engaged: (i) authorities and public servants representing constitutional governance (government); (ii) delegates from collective governance, including communities, civic organisations, technocrats, academics, and researchers; and (iii) service providers and users representing operational governance.^{25,61} This mapping closely matches the categories of interest-holders formalised in the World Health Organization’s *Strategic Approach to Urban Health* and associated policy briefs published in 2024 and 2025.^{7,10,156,207}



Publication 1 – a theory of change to guide the protocol and interest-holder analyses¹⁵⁸ (Zoom or click for detailed view)

3.4.1 *Outputs and communication tools*

Central to this engagement was the development of communication tools that translated complex analyses into accessible formats. A four-minute video animation (Video 1) and infographic (Figure 6) were created to present the policy problem, the methodological approach, and the project's vision in a relatable manner. These tools incorporated local cultural elements, bilingual narration, and music to enhance contextual resonance.^{217–219} They were piloted with key informants and collaborators (Figure 5), refined through iterative feedback, and subsequently used as teasers to spark curiosity, invite contributions, and promote dialogue across diverse governance levels.

These communication tools were illustrative and constituted integral components of the participatory methodology. By enabling effective engagement with knowledge users and other interest-holders, they strengthened the project's people-centred approach and exemplified efficient knowledge translation into policy and practice.

The approved protocol was published in 2022 in F1000Research, with the Theory of Change. F1000Research is a digital journal with a [105 H-index](#) and [Scimago Journal Rank of Q1](#) for three knowledge areas, including Medicine. By May 2025, it had about 1,000 views. The embedded document is in Annexe 9.1.

- Cuervo, LG, Jaramillo C, Cuervo D, Martínez-Herrera E, Hatcher-Roberts J, Pinilla LF, Bula MO, Osorio L, Zapata P, Piquero Villegas F, Ospina MB, and Villamizar CJ. **“Dynamic Geographical Accessibility Assessments to Improve Health Equity: Protocol for a Test Case in Cali, Colombia.”** F1000Research, November 28, 2022.

<https://doi.org/10.12688/f1000research.127294.1>

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STUDY PROTOCOL

Dynamic geographical accessibility assessments to improve health equity: protocol for a test case in Cali, Colombia

[version 1; peer review: 2 approved]

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Publication 2: Approved study protocol ⁶ (Click on the image to open the file)

The selection of networks, sectors, and interest holders was informed by Abimbola’s proposed multi-level framework for analysing primary health care governance. It proved well aligned with the WHO’s Strategic Approach to Urban Health and its Policy Briefs.^{7,10,25,49–51}

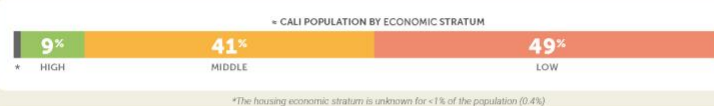
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HEALTH IN CALI

ACCESSIBILITY AND EQUITY

Equity is a challenge for urban planning, as the involved sectors currently work with different data, knowledge, and approaches.

The AMORE Project facilitates intersectoral collaboration, providing common-usage data, and presenting solutions drawn around equity, to improve accessibility to essential health services.



Health services are concentrated towards the center-west of the city, while the majority of the population resides in the periphery. This causes significant inequities in accessibility, especially for people in the middle and lower income strata.



URGENT CARE

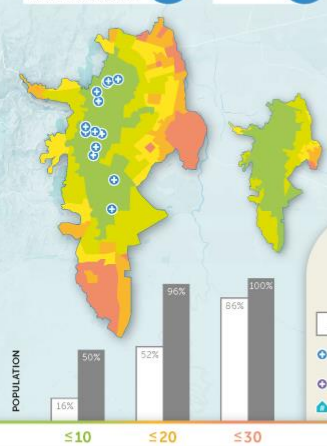
There are medical emergencies that must be looked after in high-complexity institutions with emergency services. **The travel time** to the service centres defines the prognosis of patients and affects public welfare.

NUMBER OF HIGH COMPLEXITY CENTRES WITH EMERGENCY SERVICES

14

INTENSIVE CARE BEDS

481



FREQUENT CARE

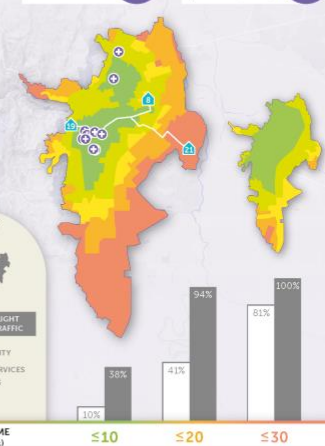
There are essential treatments such as haemodialysis that require frequent sessions. **The cost of transport** to reach these health services, affects the many sectors of the population differently.

NUMBER OF HAEMODIALYSIS CENTRES

11

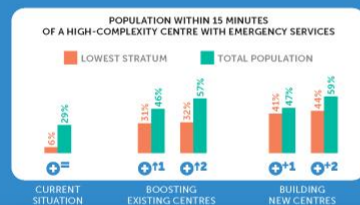
FREQUENCY OF TREATMENT (SESSIONS/WEEK)

3-5



The traffic level is proportional to the duration of the trip: congestion is worse during the day (11:00-19:00) than late at night (00:00-06:00).

The general coverage of high-complexity services can be extended by **boosting existing centres**, and/or by **building new institutions**. This, in turn, has the potential to improve health equity for all the different sectors of the population.



The monthly cost of transport corresponding to the trips to haemodialysis centres can affect a patient's quality of life. **This cost represents a variable proportion of a family's monthly wage**, taxing more families traveling longer times, such as low income families.



*My estimate cost of a round trip by taxi, three times a week to the nearest haemodialysis centre.



These visualizations can help different stakeholders to **collaborate in the search for solutions developed in an intersectoral manner**, to improve health equity and accessibility.



This approach can be applied to other public goods, such as education, justice, or emergency response, thus contributing to the Sustainable Development Goals.



AMORE Project

IQUARTIL

Dr Luis Gabriel Cuervo - luisgabriel.cuervo@e-campus.uab.cat

Figure 6: 2020 Infographic with preliminary data. (Zoom or click for a detailed view)

3.4.2 Prototypes of the web-based AMORE Platform

An early and significant contributor to this project was Daniel Cuervo, an industrial engineer and partner at IQuartil SAS, a data science company based in Bogotá, who served as lead data scientist to the AMORE project. We discussed conceptual developments in travel-time optimisation for emergency services before the initiation of the doctoral programme, and Eng. Cuervo advised the project throughout its evolution, participating in consultations with knowledge users, other contributors, and key informants, supporting the leadership and guiding the data sciences team—a practice recommended for the development of digital platforms.⁵⁶

At the time this doctoral research commenced, the Ministry of Information and Communication Technologies of Colombia (MinTIC), in collaboration with the Colombian government and CorrelationOne, launched the *Data Science for All* (DS4A) certificate programme to strengthen national capacities in artificial intelligence and data science. This initiative sought to address local needs through a nationally scalable training programme designed to certify data scientists in Colombia.^{220,221} It was also a competitive process with more than 12,000 applicants. Daniel Cuervo was one of the 537 selected participants to DS4A who joined from 45 cities and graduated from the 10-week training program.

The DS4A certificate program assigned participants to small teams that developed real-world capstone projects, applying their skills to address pressing development challenges in Colombia and to build the country's AI ecosystem. Daniel Cuervo was assigned to “Team 33”, one of the 92 project teams established. Daniel shared with them the project's concept of an interactive digital platform that integrated big and open data to assess and predict accessibility by measuring the interactions between traffic congestion, travel times to essential health services, and health equity, supporting the project's objectives (see page 25).²²²

Team 33 held weekly and ad hoc meetings with the doctoral researcher to define needs and requirements, review draft versions, and share developments with key

informants and collaborators, while iteratively testing models (Figure 7) in accordance with best practices.^{56,223} Team 33 was one of the top five teams to reach the programme's grand finale and present to CorrelationOne trainers, MinTIC's leadership, other DS4A participants, and government and academic representatives.²²⁴

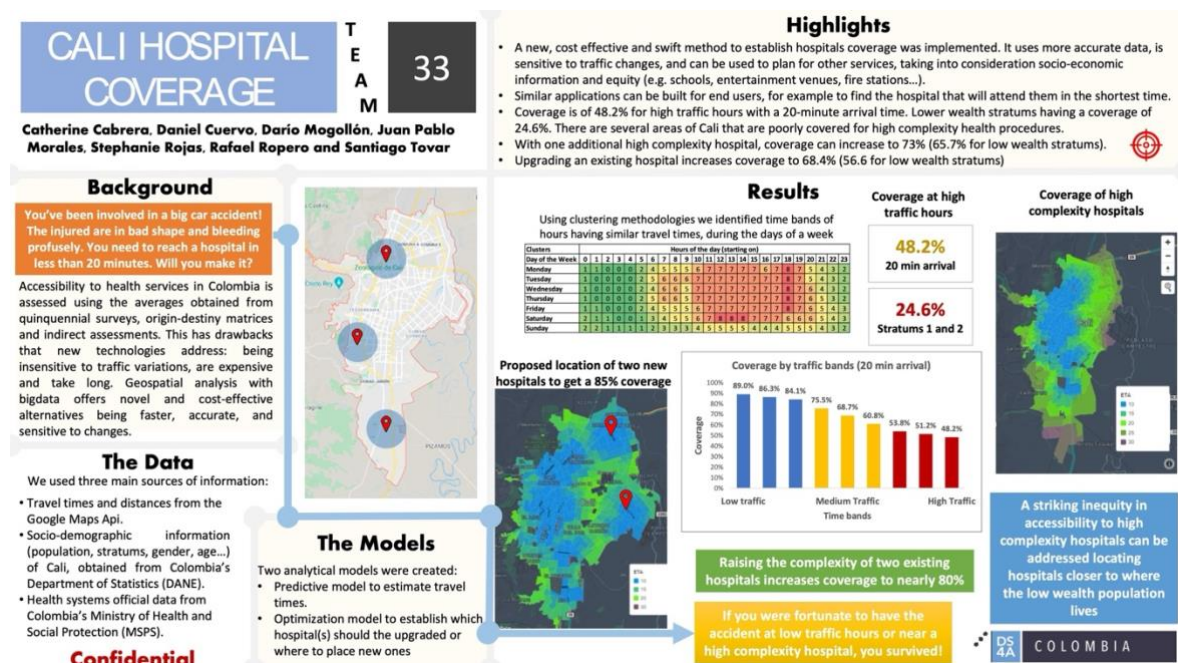


Figure 7: Team 33 data folio, prepared with AMORE Project's guidance.²²⁴(Zoom or click for a detailed view)

Three prototypes were completed during the DS4A programme. Team 33 utilised these "Series 1" prototypes for training and their final presentation (Figure 9).²²⁴ The development processes are summarised in Figure 7 and Figure 8.

3.4.1 Platform development workflow

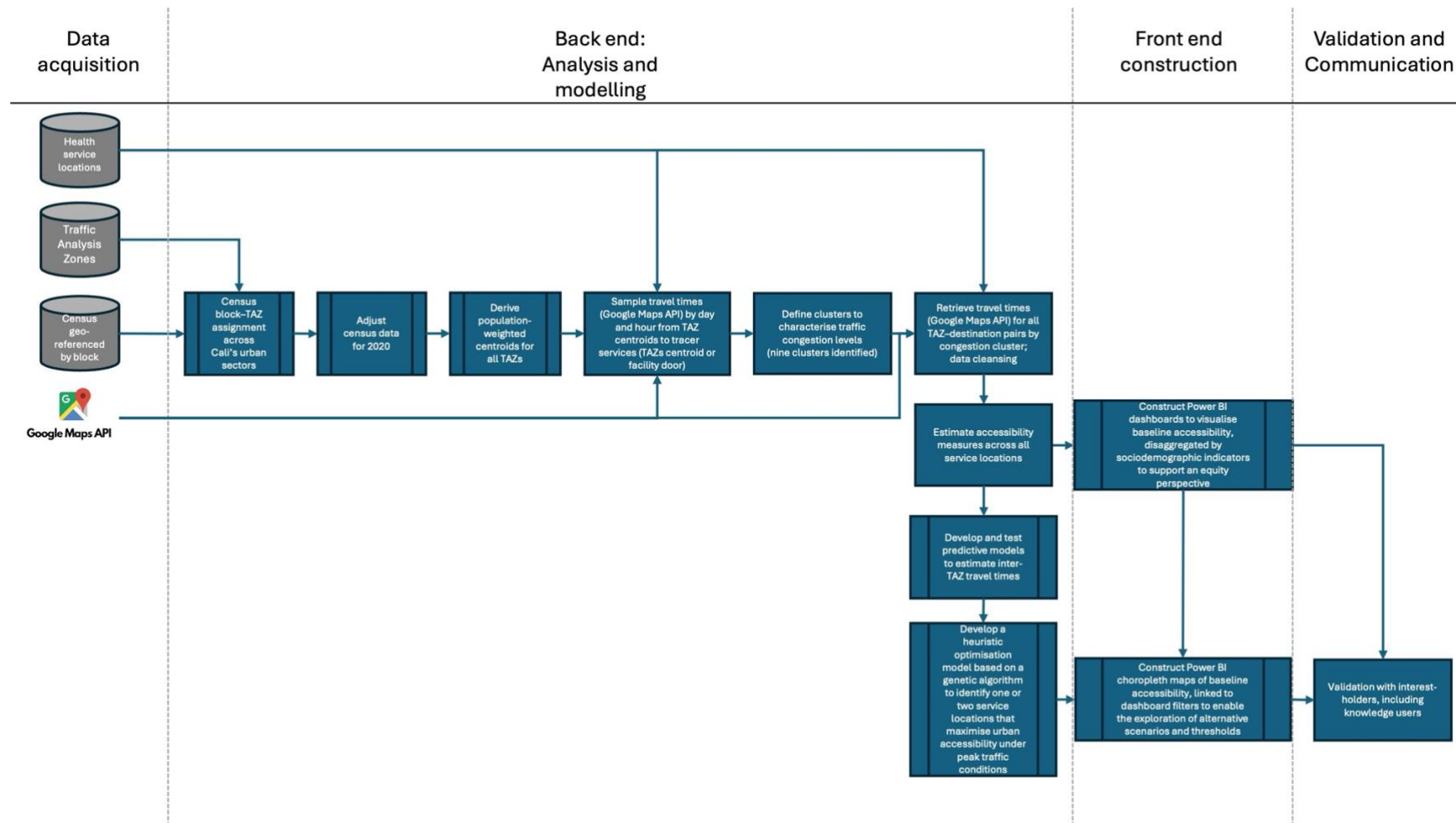


Figure 8: AMORE platform development workflow (high-resolution; optimised for zooming)

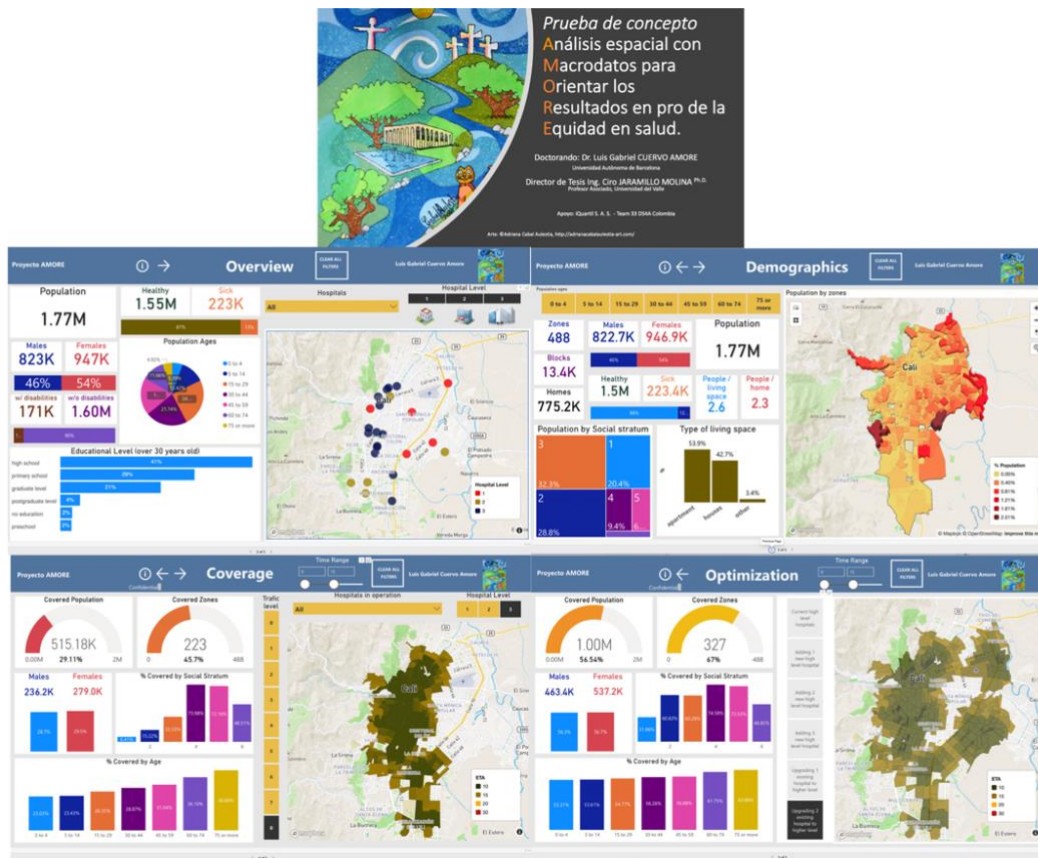


Figure 9: Interfaces for the five screens of AMORE Platform v1.3-20210212 (zoom or click for a detailed view)

Following completion of the programme, Team 33 was dissolved, and subsequent prototypes were developed and refined in collaboration with IQuartil SAS, the data science company contracted to continue the work.

Eng. Daniel Cuervo and Eng. Luis Fernando Pinilla provided programming support to integrate additional haemodialysis and radiotherapy services into the platform, enhance user interfaces, incorporate adjusted census data, and improve prototype performance. As the project progressed, Eng. Pinilla left IQuartil SAS and was replaced by Eng. Pablo Zapata, who took on programming responsibilities, contributed to data visualisation, final prototypes, and brought in valuable perspectives from lived experiences.

Prototype 2 integrated these enhancements and added accessibility predictions to situational analyses for the three tracer services (haemodialysis, radiotherapy, and tertiary emergency care), representing both chronic and acute essential healthcare.²²⁵ It utilised adjusted census data and measurement data from July and November 2020, presented in a vertical layout with separate interfaces. Version 2 was released on 12 February 2021.

Subsequent releases progressively incorporated improvements. On 18 February 2021, user feedback informed the adoption of new colour palettes recommended by designers and potential users. On 29 March 2021, a release added Spanish-language interfaces and displayed predictions for additional services. A later version, released on 3 September 2021, included design refinements and error corrections, such as verification of coordinates for a misplaced service. Based on user testing, the platform reverted from a vertical to a landscape format to match typical monitor proportions. This adjustment was implemented in Version 3, released on 6 February 2022, which also introduced bilingual interfaces (Figure 11).

A subsequent release on 14 March 2022 incorporated an additional interface with tables that simplified data collection for publication, grouping socioeconomic strata into low (1–2), medium (3–4), and high (5–6), following conventions in Colombian public health reporting. On 23 March 2022, further corrections included adjustments to service coordinates. We then measured travel times from the population-weighted centroids of each residential Traffic Analysis Zone (TAZ) to the centroids of service-hosting TAZs. While this could introduce slight reductions in precision, these are likely to be negligible for urban and health services planning, and TAZs substantially simplify computations. We analysed 14 tertiary emergency services, 11 haemodialysis units, and five radiotherapy facilities across 507 TAZs and 15 service-hosting TAZs.

Version 3 was the final set of prototypes used for reporting. They included bilingual interfaces, dedicated English interfaces for publication screenshots (as requested by

journals), and supplementary tables and figures (Figure 10, Figure 11, Figure 12 and Figure 13). The platform's interactive maps could be expanded and rotated, providing three-dimensional choropleth visualisations that linked travel times to TAZs (Figure 10). These maps revealed that health services were concentrated far from densely populated eastern areas and peripheral neighbourhoods—patterns also documented in other Latin American cities.²²⁶

Good practices applied during development included the continuous involvement of data scientists throughout the conceptualisation, development, and implementation phases.⁵⁶ The process incorporated design thinking and AGILE methodologies, and prototypes were made publicly accessible to enable knowledge users to explore scenarios, validate findings, and contribute ideas for further improvements.

44,73,74,185,223

The interactive nature of the AMORE Platform, allowing users to modify parameters, was considered essential to avoid reliance on impractical fixed thresholds for policymaking.⁹ This feature is particularly relevant given the absence of standardised benchmarks for travel times, a variable that is inherently continuous and context-dependent.

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Figure 10: Composite images of the platform used for published reports. This is Figure 2 of the report on haemodialysis. (Open the file by clicking the image)

3.4.2 Applied data sciences

The presentation layer of the AMORE Platform (the *front end*; Figure 9 and Figure 11) was developed using Microsoft Power BI™ and displays descriptive and bivariate statistics through dashboards that integrate filters and heatmaps (choropleth maps). Interactive images functioned as filters, enabling users to select or combine

sociodemographic variables, travel times, health services, and traffic congestion levels. This design was tested for accessibility and comprehension with diverse interest-holders, including non-specialists and the wider public.^{80,152,153,211,227}

Iterative consultations with key informants, data end-users, science communicators, and experts guided refinements to improve clarity and design. Feedback from knowledge users at every stage of development provided data scientists with a deep understanding of the contextual challenges and needs. Applying design thinking principles, the team refined interface layouts, presentation logic, and colour coding of visual elements.⁷³

The platform's data access and processing layer (the *back end*) was developed using Python (Python Software Foundation) and the Konstanz Information Miner (KNIME). Python was applied for artificial intelligence routines, machine learning, and geometric operations within geographic information systems. KNIME, while not natively geospatial, was utilised for statistical analyses and demonstrated a strong capacity for data extraction, transformation, and loading.^{6,228}

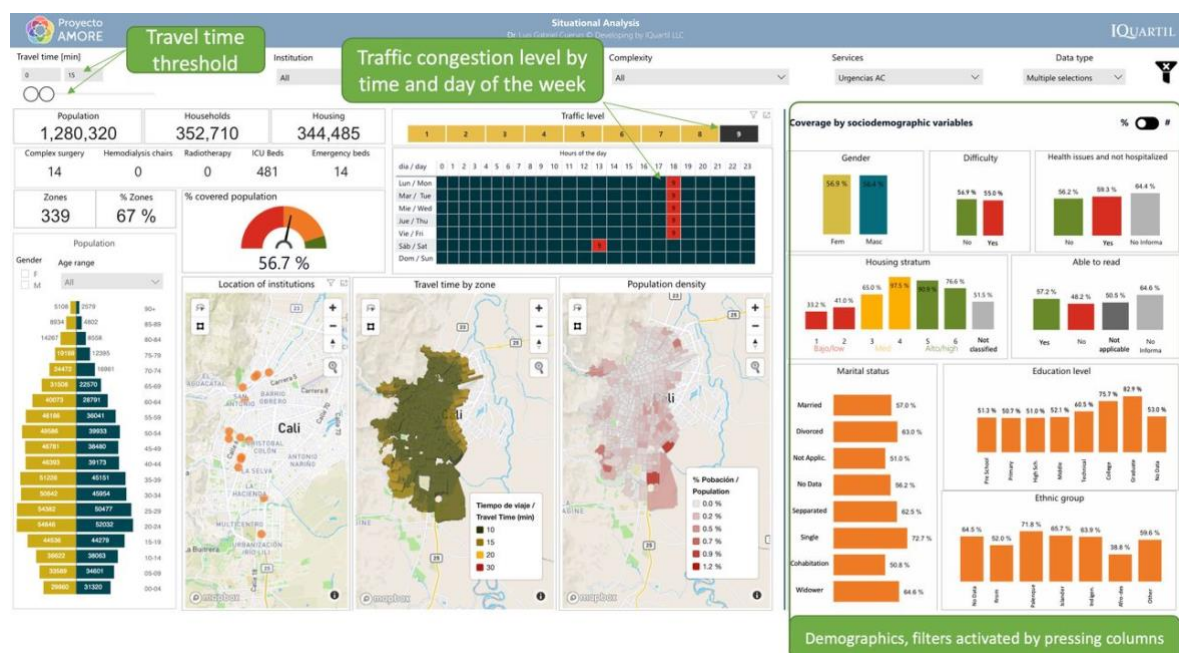


Figure 11: Situational analysis for accessibility by car, November 2020. Interface and filters.⁸²

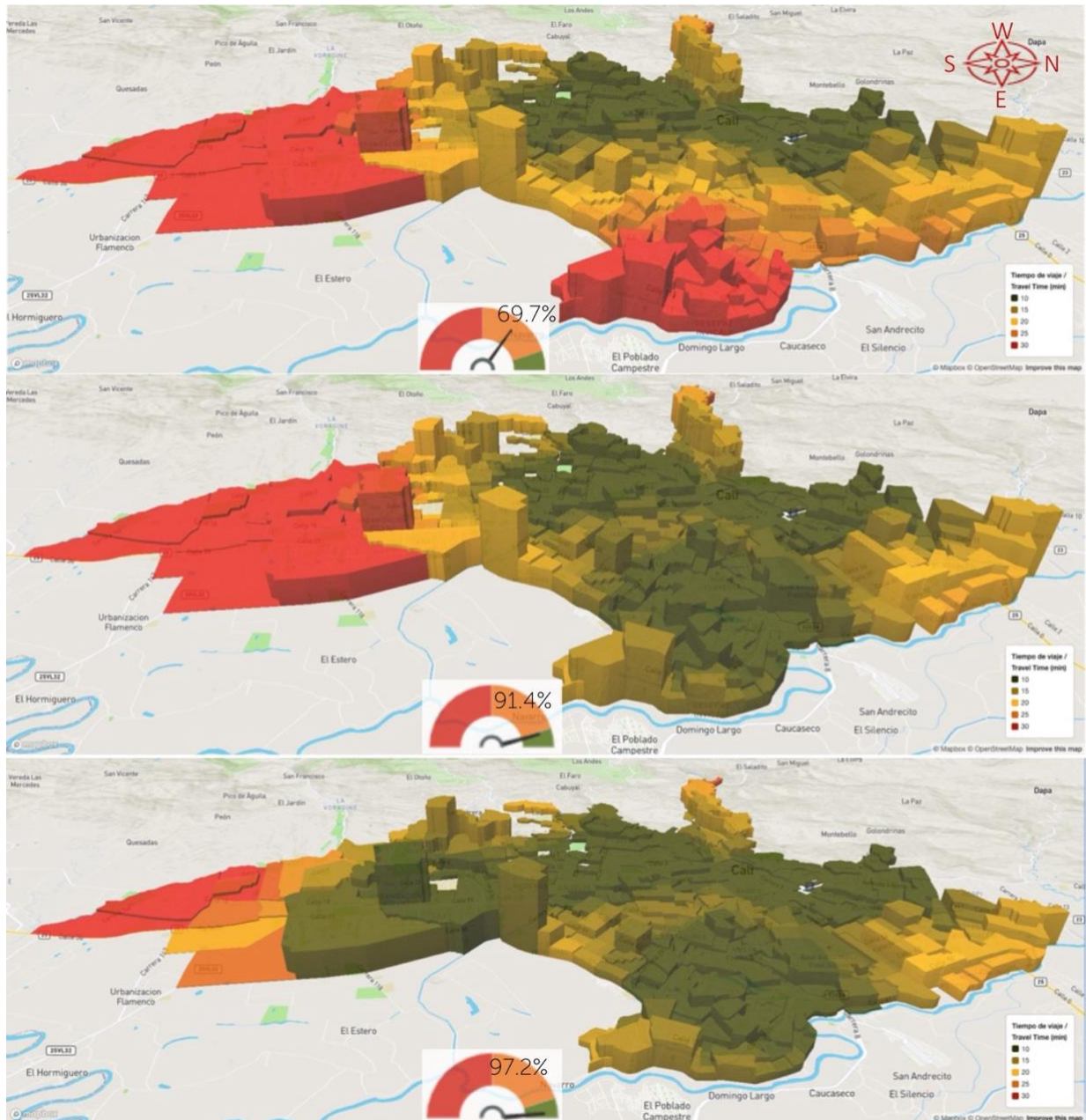


Figure 12 Baseline car accessibility to haemodialysis in November 2020 and projected improvements from strategically adding services in one or two traffic analysis zones (TAZs) that maximise accessibility.⁸¹ Top panel: baseline assessment (23–29 November 2020). Middle panel: accessibility prediction after adding one optimising TAZ. Bottom panel: accessibility after adding two optimising TAZs. (Open the file by clicking the image)

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15-minute accessibility by car to tertiary care emergency services in Cali,
using Google Distance Matrix API measurements for 6-12 July, 2020, plus predictions if services were strategically added

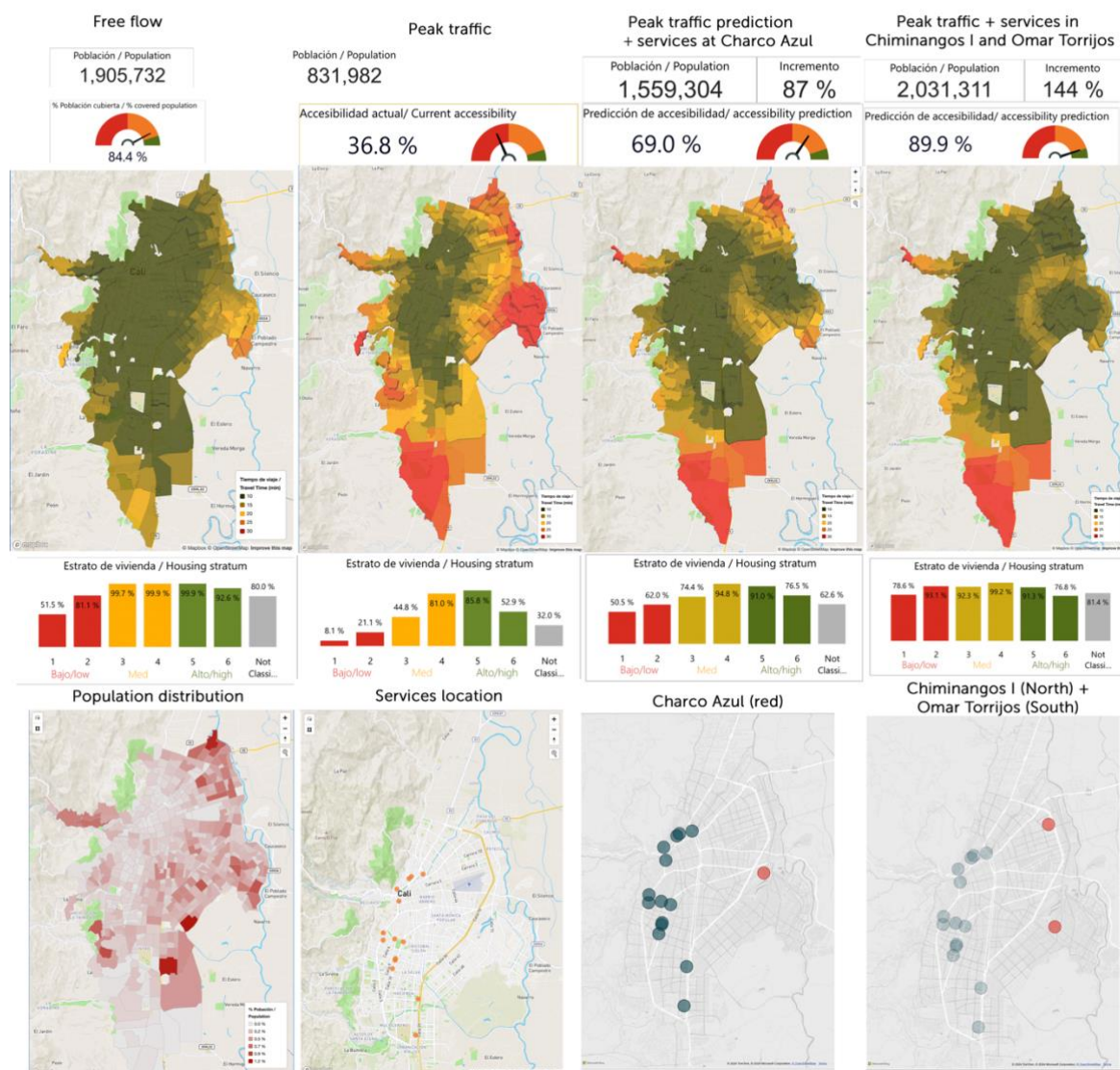


Figure 13 Collage of AMORE Platform images showing accessibility baseline and potential improvements for tertiary care emergency services based on the July 2020 travel time measurements.¹¹⁶ (Open the file by clicking the image)

3.4.3 Using open and big data to assess accessibility

The AMORE Platform integrated multiple data layers.⁶

1. **Georeferenced data on tracer services.** Case studies included tertiary emergency hospitals, haemodialysis units, and radiotherapy services obtained from Colombia's National Special Registry of Health Service Providers (REPS). Specifically, Cali's 14 tertiary hospitals with emergency care

(REPS “Alta complejidad” + 501), 11 haemodialysis units (370 chairs, REPS 733), and 5 radiotherapy services (REPS 711).

2. **Georeferenced population and housing microdata.** Colombia’s 2018 census (DANE) was adjusted to reflect 2020 conditions, accounting for intercensal growth, under-registration (18%), and migration by randomly duplicating 28.1% of the population. These adjustments did not produce significant differences compared with the unadjusted data, but improved representativeness for publications. The platform allows toggling between adjusted and unadjusted data.^{229,230}
3. **Traffic Analysis Zones (TAZs).** Based on the 2015 database, complemented by census sectors for areas without TAZ coverage. TAZs offered adequate granularity for accessibility analyses with far fewer data demands than block-level units (507 TAZs versus 13,558 blocks).^{79,81,82,116} Population-weighted centroids were calculated to more accurately represent residential concentrations (Figure 14).
4. **Travel-time big data.** Hourly car travel times between 507 origin TAZs and 15 service-hosting TAZs were procured for two representative pandemic weeks with differing mobility restrictions: 6–12 July 2020 and 23–29 November 2020.^{79,81,82,116} Travel-time clusters were derived using k-means, reducing the dataset from 168 hourly measurements per week to 9 representative congestion clusters, thereby reducing data needs by three orders of magnitude.^{6,82,116}

The integration of these datasets enabled situational analyses that underpinned the three core publications derived from this research.

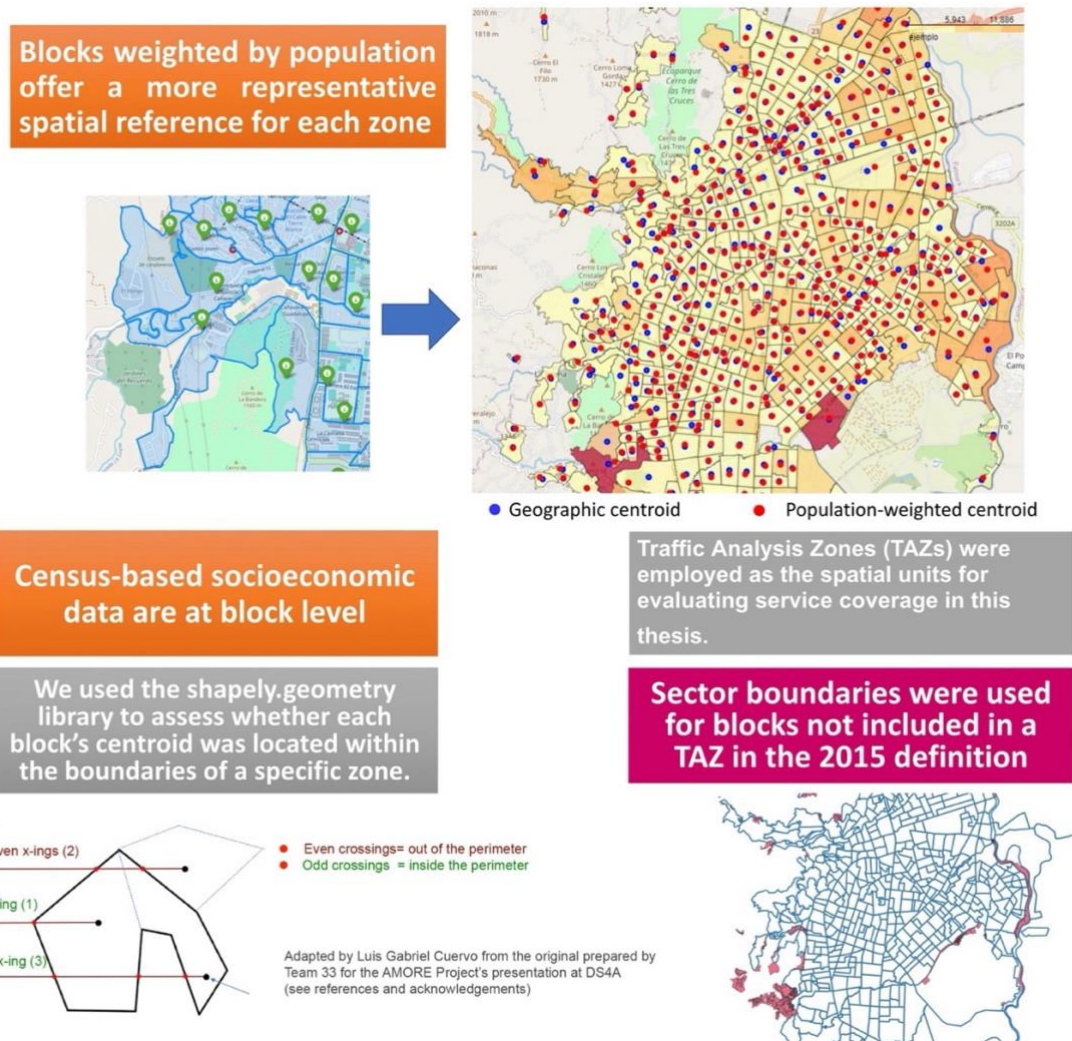


Figure 14: Definition of population-weighted centroids for each TAZ and sectors

3.4.4 Identifying where to locate new services to optimise urban accessibility

Once travel times were measured and disaggregated by sociodemographic group and spatial unit, it became necessary to identify locations where additional services could maximise urban accessibility. Measuring every possible TAZ combination (507×506) across congestion clusters would have required prohibitive computational resources.

To address this, a predictive optimisation model was developed using a computational optimisation method inspired by biological evolution called a genetic algorithm. The algorithm iteratively selected TAZs without services, compared

accessibility gains with those of neighbouring TAZs (mutations), and repeated the process until no further improvements were possible. After 50 iterations, the best-performing TAZ was selected. The algorithm produced results in minutes, allowing feasible computation on standard computers or laptops.

Comparisons with a recursive exhaustive model showed equivalent results. However, the recursive model was highly resource-intensive, requiring several days of processing to evaluate multiple service locations. The genetic algorithm, therefore, provided a practical and efficient alternative for identifying TAZs where new services would yield the greatest improvements in accessibility.^{231–233}

3.5 Summary of methods

The analyses and prototypes presented in Section 3.3 provided the empirical and methodological basis for synthesising broader insights. These are summarised here as key messages with relevance for policy, practice, and future research.

Aligning urban and health agendas to address the impact of traffic congestion on accessibility and equity represents a complex policy challenge. Addressing this challenge requires intersectoral collaboration and a pragmatic research approach oriented towards implementation and actionable policy insights. This study adopted a people-centred methodology, combining research, implementation, and knowledge exchange tools to engage diverse interest-holders in the planning of urban and health services.

Through a participatory, intersectoral network of volunteer contributors and key informants, the project examined the links between traffic congestion, travel time to essential health services, and equity in geographical accessibility. This work contributes to advancing the Sustainable Development Goals (SDGs), recognising their interconnected and multidimensional nature. While geographical accessibility is a recognised social determinant of health, its relationship with traffic congestion and

equity has remained underexplored in many urban settings where congestion is increasingly prevalent.^{8,234,235}

Interest-holders contributed directly to the conceptualisation, enhancement, and application of digital tools to measure and predict access to essential health services. Their engagement went beyond the research team, fostering awareness and momentum for adopting metrics that account for temporal variation (time of day and week) and equity considerations. This participatory process was operationalised through a web-based digital platform that integrated open and big data to measure and predict cumulative accessibility opportunities for three tracer health services, representing both chronic and acute care.

Three case studies were conducted in Cali, Colombia, assessing accessibility at two time points in 2020. The AMORE Platform demonstrated the capacity to model potential improvements in accessibility if new services were introduced, and to identify urban sectors where such additions would yield the greatest optimisation, thereby providing actionable evidence for decision-makers in urban and health planning.

Beyond technical outputs, the project fostered intersectoral and multi-interest-holder dialogue on aligning urban and health planning. Participants included opinion leaders, academic institutions, government authorities, data scientists, technical experts, service providers, and civil society representatives such as patient groups and civic organisations. Research results were disseminated through open-access publications, multimedia content tailored for diverse audiences, and professional platforms such as LinkedIn. From inception to dissemination, the project was discussed in local and international forums, engaging actors across sectors,

including data scientists, science communicators, and specialists in public policy and political science (Page 287, Figure 21).^{93,147}

Planning and findings were also presented at local events coordinated with Cali's leading academic institution, promoting the timely translation of knowledge into public policy. This facilitated the integration of research insights into decision-making, as reflected in Cali's 2024–2027 Development Plan and evolving land-use strategies. The project further strengthened the evidence base on health service accessibility, inspired postgraduate research, and informed civic and institutional debates. For example, Propacífico^{Footnote 4} and City Cancer Challenge^{Footnote 5} continued collaborating with the AMORE Project, Universidad del Valle, and service providers to explore the role of accessibility in healthcare pathways and to develop strategies to reduce diagnostic confirmation times for breast cancer.

Taken together, these contributions demonstrate the feasibility and utility of a participatory, data-driven approach for aligning urban and health agendas, advancing equity, and accelerating the translation of research into actionable policy and planning.

The following chapter situates these findings within the broader body of evidence, discusses their implications for policy and practice, and outlines opportunities for future research.

[CHAPTER SEPARATION - SPACE INTENTIONALLY LEFT BLANK]

⁴ <https://propacifico.org/en/>

⁵ <https://citycancerchallenge.org/>

4 Results

We explored the policy problem of determining the links between traffic congestion, health equity, and accessibility by:

- We developed an interactive web-based platform that illustrates the effects of traffic congestion on travel times for TAZs and populations, quantifying accessibility. The platform also identifies one or two TAZs where new services would maximise urban accessibility, illustrating, graphically and with measurements, the potential improvement.
- We engaged diverse knowledge users and other interest-holders throughout the conceptualisation, implementation, reporting, and advocacy that enabled the translation of findings into policy.
- We engaged with expert and non-specialist audiences interested in operational implementation and in advancing public policy analysis beyond problem description.^{9,10,12–14,37,49–51,54,153,154,205,211,227,236–238}
- We inspired further research and sustained momentum, as the approach and outputs were considered for adoption and adaptation by intergovernmental organisations, research groups, and NGOs, as documented in the AMORE Project's repository of products and collaborations, and thesis reports.^{54,80,83,91,93,131,132,213,239–252}

To facilitate communication of this approach and to engage diverse audiences, an infographic and several videos were produced to summarise the AMORE Project and the platform (e.g., Figure 15). Infographics, videos, animations (e.g., Figure 16 and Figure 17) and presentations aimed to communicate the policy problem, methodological approach, and platform features in accessible formats for diverse interest-holders. Beyond local use in Cali, it has been employed in academic, civic, and intergovernmental forums, contributing to broader uptake of the approach and inspiring collaborations as documented in the AMORE Project's Padlet repository.⁹³



AMORE
Project

ENABLING DATA-DRIVEN URBAN AND HEALTH SERVICES PLANNING

Use of open data to reveal the links between traffic congestion, accessibility, and equity

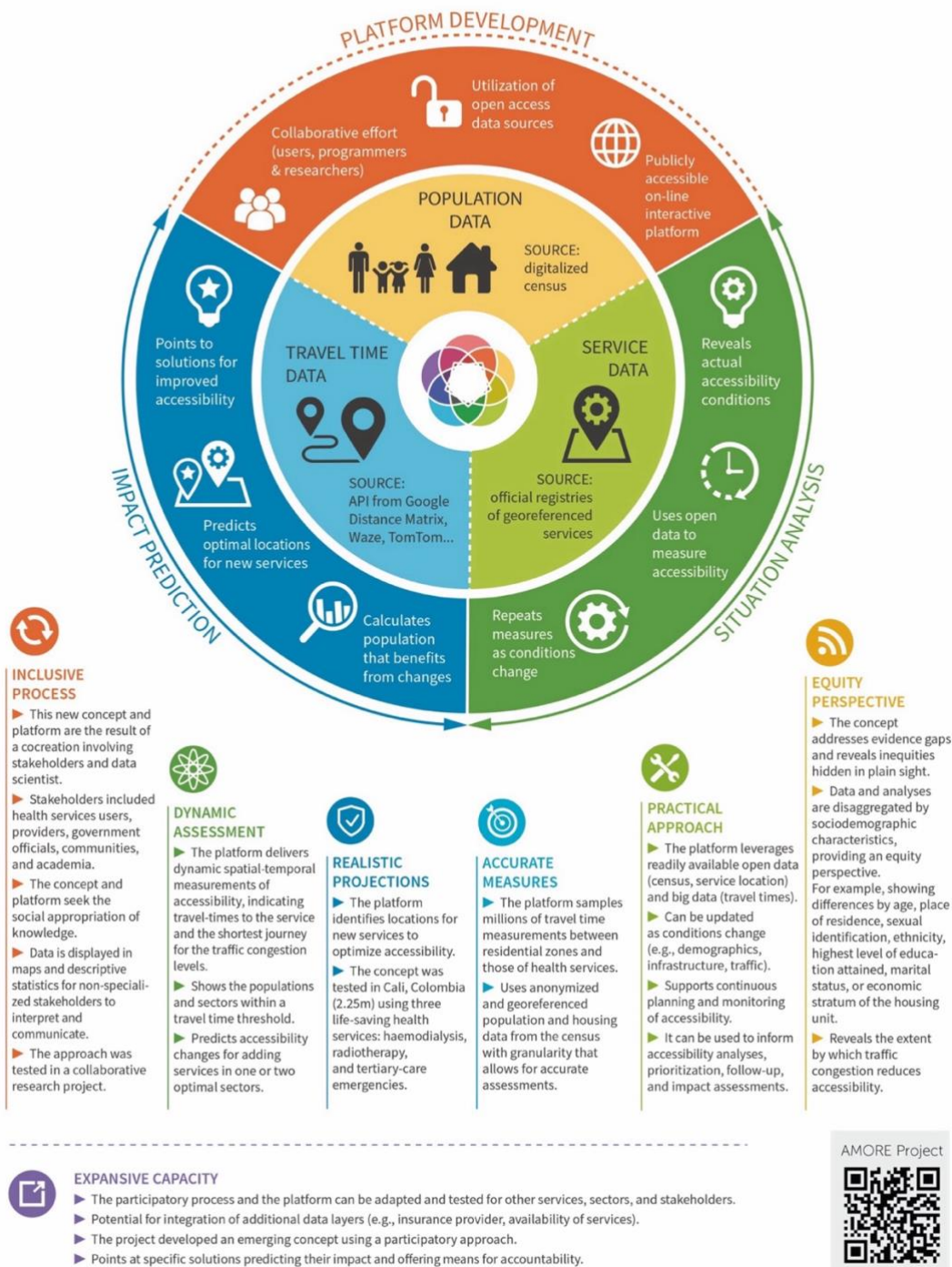


Figure 1 Infographic for the AMORE Project and platform.⁸¹ (Open the file by clicking the image)

Outcomes:

- Cumulative accessibility assessments by car for three tracer services—tertiary emergency care (acute, time-critical), haemodialysis, and radiotherapy (chronic high-cost care)—during two study weeks (6–12 July and 23–29 November 2020). Accessibility was reported at 15-minute travel thresholds for tertiary emergency services and 20-minute thresholds for haemodialysis and radiotherapy. The interactive platform enables exploration of alternative parameters.^{80,239,252,253}
- Prediction of cumulative accessibility gains under scenarios in which services were strategically added at one or two TAZs to maximise urban accessibility.^{79,81,116}
- Demonstrated that including traffic congestion in assessments yielded credible assessments and predictions to inform public policy and interest holder deliberations. This was conveyed through animated images such as Figure 2 and Figure 17 (click to activate the animations).²⁵⁴

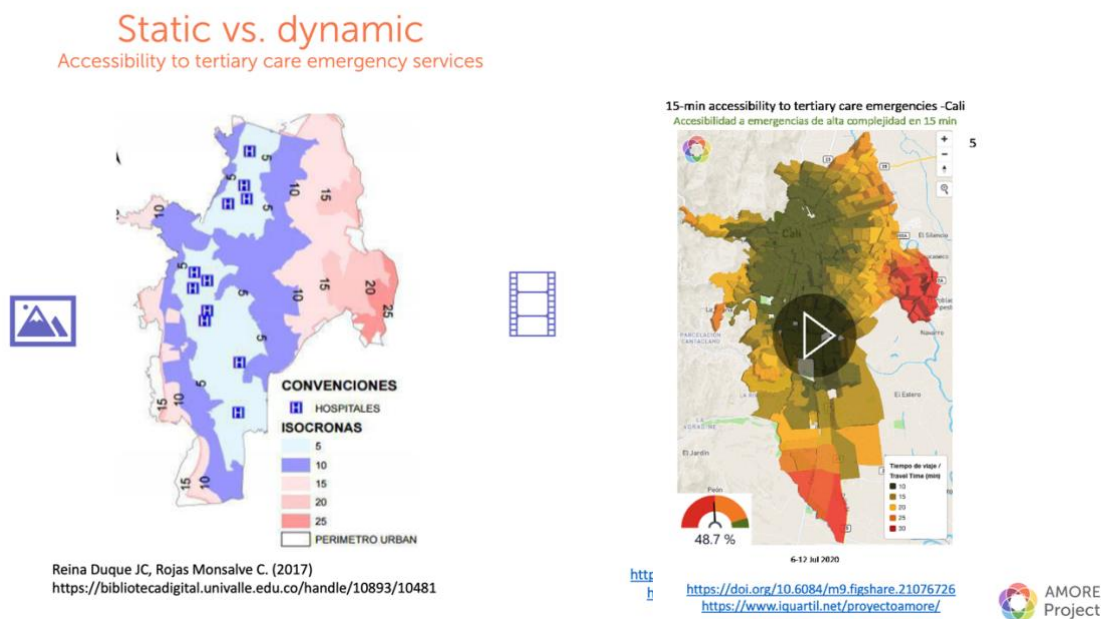
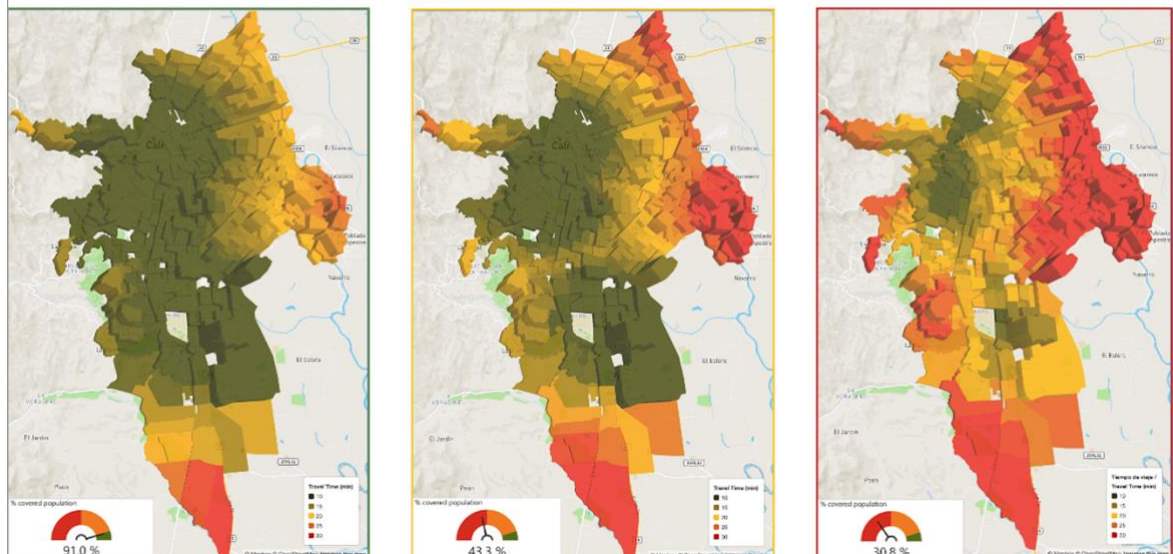


Figure 2: Static vs Dynamic assessment. Digital versions (animated right image) show changing accessibility as traffic congestion increases.²⁵⁴ (Open the file by clicking the image)

20-min accessibility rates to radiotherapy drop as traffic congestion grows.



Distributional impacts. More than half of Cali’s residents face long car journeys to reach the tracer services during regular service hours. These access barriers disproportionately affect residents of the East, Northeast, and Agua Blanca districts, as well as peripheral communities. Accessibility declines most steeply under congested conditions for those in the lowest socioeconomic strata, though the problem is not exclusive to the poor. Approximately half of the highest-income stratum (around 4% of the population), residing in sparsely populated southern areas, also experience poor accessibility. Residents in low-income housing are primarily concentrated in dense outlying urban areas, including the East, Northeast, Agua Blanca, and the western foothills along the road to the Pacific, with particularly affected neighbourhoods such as Terrón Colorado, Siloé, and areas between the Meléndez and Cañaveralejo river basins in Commune 18. These inequities have been corroborated in testimonies reported in our publications.^{79,81,82,116,128,131–133,256–259}

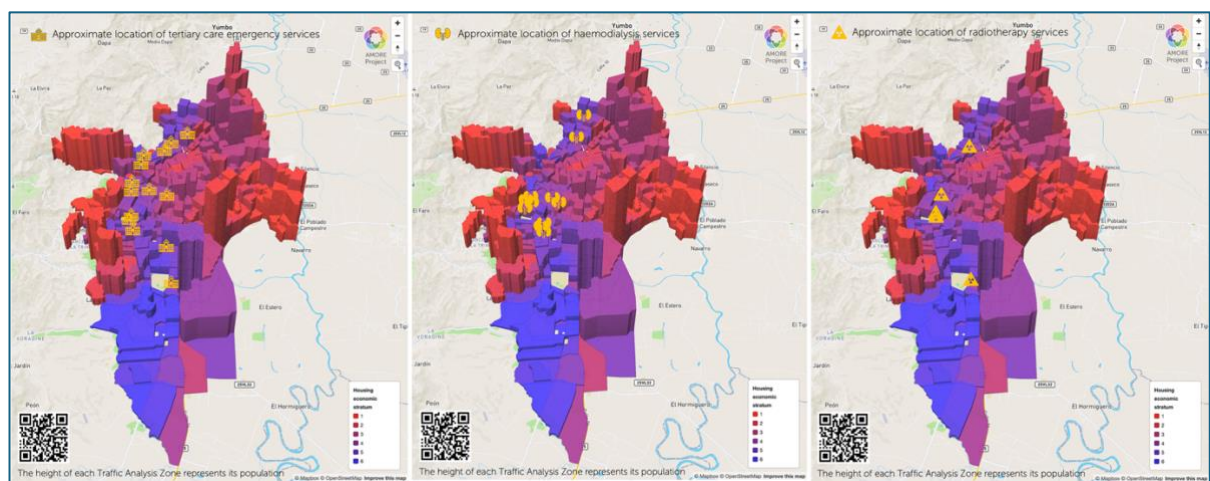


Figure 4 Location of tracer services, population, and dominant housing socioeconomic stratum for each TAZ.¹¹⁶

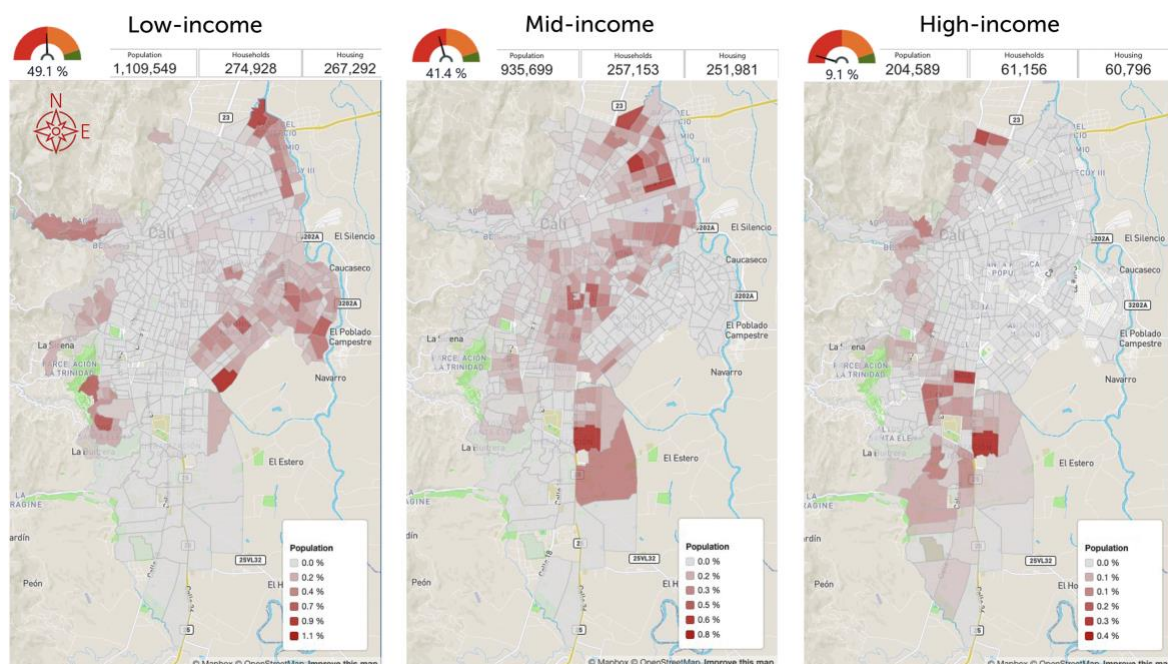


Figure 5 Cali's socioeconomic segregation as displayed in the AMORE Platform's displays.⁸¹

Figure 4 and Figure 5 illustrate Cali's pronounced socioeconomic geographic segregation, with tracer services clustered in affluent, low-density areas along the South–North corridor. For all three tracer services, congestion sharply reduced accessibility, particularly for residents of outlying districts, low-income housing, populations with lower educational attainment, and minority groups such as Afro-descendant communities.

Policy-relevant predictions. Modelled scenarios demonstrated that exclusion from services is responsive to interventions that locate services closer to where people live. Predictions indicated that if service fragmentation were addressed, strategically placed additional services could substantially mitigate the effects of congestion. Travel times for most residents could be reduced to levels comparable to those under free-flow conditions (e.g., late at night or early in the morning). While this study could be refined to compare the relative benefits of developing new services versus upgrading existing facilities—an approach tested in early prototypes—the findings are sufficient to emphasise the need to expand coverage and address inequities. Land-use plans and service delivery strategies should prioritise the eastern and

southeastern neighbourhoods, where new integrated services would most effectively reduce disparities.

Common goals: The diverse group of contributors remained active and engaged throughout the study. They participated in meetings, responded to communications, tested the platform, validated findings, and proposed improvements to analytical outputs and reports. Several contributors also provided testimonies or formally represented the project in external forums, reporting back to the collaboration, sharing data and contextual knowledge, and participating in the devolution of results to wider audiences. This sustained involvement demonstrates a high degree of ownership, engagement, and commitment, particularly given the demanding nature of these processes and the tight timelines involved.

The strategic objectives established through the participatory approach and methodology were met and, in several respects, exceeded. This is evidenced by citations of project findings in policy documents, case studies, and peer-reviewed publications; the commissioning of reference book chapters (ongoing); and participation in working groups that have continued beyond the completion of the doctoral work. The project has effectively acquired momentum of its own. Academic collaborators continue to mentor graduate students working on topics that build directly on the project's contributions, while international organisations that were not initially engaged are now partnering to develop public goods. These efforts advance traffic-sensitive accessibility metrics with an explicit equity lens and further extend the methodological approach. In addition, peers and authors of related research have proactively engaged with the project and its findings.

1.1 Core compendium publications

Diverse interest-holders co-authored the three publications forming the backbone of this doctoral compendium. Collaborators who joined the project were invited to contribute according to their roles, which were recognised using the CRediT

(Contributor Role Taxonomy, credit.niso.org) framework. Contributorship and authorship were assigned following the recommendations of the International Committee of Medical Journal Editors (ICMJE). All acknowledged contributors and authors reviewed and approved the manuscripts and disclosed potential conflicts of interest in accordance with ICMJE requirements.^{260,261}

The three publications listed below constitute the core of the doctoral compendium. Each is introduced with a summary that specifies its order in the compilation, the journal of publication, the corresponding journal metrics, and a brief description of its content. The introductions are followed by the required embedded articles, presented in sequence, to demonstrate both their individual contributions and their collective role in advancing a participatory, data-driven approach to understanding the effects of traffic congestion on healthcare accessibility and equity.

1.1.1 BMJ Open – Accessibility to tertiary care emergency services.

The first publication of the compendium was in *BMJ Open*, a journal with an [H-index of 176](#) and ranked Q1 in Medicine by Scimago. By the end of 2025, it had received nineteen citations, over 5,400 abstract views, and 6,350 full-text downloads. This report presents cumulative dynamic accessibility assessments for tertiary care emergency services in Cali, Colombia

- Cuervo LG, Martínez-Herrera E, Osorio L, Hatcher-Roberts J, Cuervo D, Bula MO, Pinilla LF, Piquero F, and Jaramillo C. **“Dynamic Accessibility by Car to Tertiary Care Emergency Services in Cali, Colombia, in 2020: Cross-Sectional Equity Analyses Using Travel-Time Big Data from a Google API.”** *BMJ Open* 12, no. 9 (September 1, 2022): e062178.
<https://doi.org/10.1136/bmjopen-2022-062178>

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Dynamic accessibility by car to tertiary care emergency services in Cali, Colombia, in 2020: cross-sectional equity analyses using travel time big data from a Google API

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Eliana Martinez-Herrera^{2, 3, 4}

Lyda Osorio⁵

Janet Hatcher-Roberts^{6, 7}

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Abstract

Objectives

To test a new approach to characterise accessibility to tertiary care emergency health services in urban Cali and assess the links between accessibility and sociodemographic factors relevant to health equity.

Design

The impact of traffic congestion on accessibility to tertiary care emergency departments was studied with an equity perspective, using a web-based digital platform that integrated publicly available digital data, including sociodemographic characteristics of the population and places of residence with travel times.

PDF

PDF + Supplementary Material

Publication 1 Situational analysis for tertiary care emergency services⁸² (Open the file by clicking the image)

BMJ Open Dynamic accessibility by car to tertiary care emergency services in Cali, Colombia, in 2020: cross-sectional equity analyses using travel time big data from a Google API

Luis Gabriel Cuervo ¹, Eliana Martinez-Herrera ^{2,3,4}, Lyda Osorio ⁵, Janet Hatcher-Roberts ^{6,7}, Daniel Cuervo ⁸, Maria Olga Bula ⁹, Luis Fernando Pinilla ¹⁰, Felipe Piquero,¹¹ Ciro Jaramillo ¹² On behalf of The AMORE Project Collaborative Group

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► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2022-062178>).

LGC, EM-H and CJ are joint senior authors.

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ABSTRACT

Objectives To test a new approach to characterise accessibility to tertiary care emergency health services in urban Cali and assess the links between accessibility and sociodemographic factors relevant to health equity.

Design The impact of traffic congestion on accessibility to tertiary care emergency departments was studied with an equity perspective, using a web-based digital platform that integrated publicly available digital data, including sociodemographic characteristics of the population and places of residence with travel times.

Setting and participants Cali, Colombia (population 2.258 million in 2020) using geographic and sociodemographic data. The study used predicted travel times downloaded for a week in July 2020 and a week in November 2020.

Primary and secondary outcomes The share of the population within a 15 min journey by car from the place of residence to the tertiary care emergency department with the shortest journey (ie, 15 min accessibility rate (15MAR)) at peak-traffic congestion hours. Sociodemographic characteristics were disaggregated for equity analyses. A time-series bivariate analysis explored accessibility rates versus housing stratification.

Results Traffic congestion sharply reduces accessibility to tertiary emergency care (eg, 15MAR was 36.8% during peak-traffic hours vs 84.4% during free-flow hours for the week of 6–12 July 2020). Traffic congestion sharply reduces accessibility to tertiary emergency care. The greatest impact fell on specific ethnic groups, people with less educational attainment and those living in low-income households or on the periphery of Cali (15MAR: 8.1% peak traffic vs 51% free-flow traffic). These populations face longer average travel times to health services than the average population.

Conclusions These findings suggest that health services and land use planning should prioritise travel times over travel distance and integrate them into urban planning. Existing technology and data can reveal inequities by integrating sociodemographic data with accurate travel times to health services estimates, providing the basis for valuable indicators.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ Our study investigated affordably measured dynamic accessibility to tertiary care emergency services for the entire population using massive amounts of measurements and provides an equity perspective.
- ⇒ The platform was developed using a person-centred design; it communicates findings using basic descriptive statistics, graphics and cartography.
- ⇒ Travel times account for traffic congestion and are a proxy for travel costs (ie, distance, cost and time).
- ⇒ Sources used to measure travel times are empirically known to be accurate, but variations of their precision across sectors and populations, like the algorithms behind the measurements, are unknown.
- ⇒ Models need to be retrained if conditions change ostensibly.

INTRODUCTION

Background and rationale

Every minute counts in life-threatening emergencies that do not leave time for referrals (eg, insufficient tissue oxygenation, critical bleeding, significant tissue damage and poisoning). The well-being of patients depends on getting immediate attention in a tertiary care facility that offers essential subspecialised care by highly skilled personnel and sophisticated facilities, including specialised surgical theatres and intensive care units.

This study tests a new approach that allows stakeholders to explore different assumptions and scenarios, for example, different time-to-destination thresholds, traffic congestion levels or accessibility for the whole or parts of the population.

The study delivers baselines for accessibility by car (automobile) to tertiary care emergency departments in Cali, Colombia. It

assesses the impact of traffic congestion on accessibility and health equity, using a car (private or for hire) as the means of transportation because it is how Cali residents typically reach tertiary care facilities in emergencies. This approach also makes it possible for future studies to analyse accessibility with other means of transportation or under different assumptions.

Accessibility is a dynamic spatial attribute measured as the travel time needed to reach a health service location (destination) from the origin of the demand (place of residence in this study).^{1–5} Travel times fluctuate over time and with traffic congestion. Accessibility has been challenging to study and monitor, and poor accessibility can be detrimental to health equity.^{4,8–10}

Traditional assessments of accessibility in urban planning seldom consider its dynamic nature; origin–destination studies and surveys usually lack a dynamic assessment showing the effects of infrastructure, population changes or traffic on accessibility and health equity.^{11,12}

Traditional assessments are onerous, done every 5–10 years, using lengthy surveys that lack the specificity of health services and the geographical granularity of traffic analysis zones or TAZs (instead of more expansive neighbourhoods or communes). The conditions assessed may have changed when results become public, rendering any proposed solutions irrelevant.^{8,13} This study explores an approach that addresses critical limitations of traditional accessibility assessments to expose the links between equity and accessibility to tertiary care emergency services.¹⁰

Innovative approaches using accessible web-based platforms are an opportunity for evidence-informed decision making and planning to improve health coverage. These platforms allow stakeholders to test assumptions and reach conclusions and capitalise on features such as big data from smartphones that can provide accurate travel-time estimates. Therefore, dynamic, affordable and updatable assessments that account for traffic congestion could be used, thus focusing on travel times instead of travel distances.^{5,8,12,14–17} They might allow stakeholders to explore data, test assumptions better and reach action-oriented conclusions.¹⁸ This study integrates the equity-relevant data we used to perform equity analyses.

Objectives

This study aims to characterise accessibility to tertiary care emergency health services in urban Cali and the links between accessibility and sociodemographic factors relevant to health equity.

METHODS

Study population and setting

This study is about emergencies requiring attention in tertiary care institutions. By early July 2020, COVID-19 pandemic-related quarantine and stay-at-home orders had been lifted, and traffic projections showed substantial congestion. By November 2020, some measures had been reinstated, car travel was restricted by licence number

and traffic projections showed reduced travel times, especially in central city areas.^{19–21}

This cross-sectional study was conducted with data downloads for the urban area of Cali, the third largest city in Colombia and the largest urban centre in the southwest and Pacific regions, with an estimated 2.258 million residents in 2020. About half of the population lives in low-income housing, 42% in middle-income housing and 8% in high-income housing. Housing stratification does not necessarily represent the income of individuals.^{22,23}

About 84% of the population identifies as white, 14% as Afro-Colombian and a small proportion as indigenous or nomadic people like the Rrom. In December 2020, unemployment rates in Cali were 26.7% for women and 18.5% for men, a 1-year increase of 12.5% and 8.8%, respectively.

The situation was worse among young people, and an estimated 52% of women and 47.2% of men relied on the informal economy. The COVID-19 pandemic punished the local economy. While one in five people was unemployed, the rates were higher among people in low-income households. Cali also absorbed 139 000 migrants from Venezuela between 2016 and 2020, including 25 000 in 2020.²⁴

Poverty, inequity and discrimination drove social unrest that led to violence after a 2021 national strike.^{25,26}

The city government is dividing its 22 communes into six to eight districts, which might lead to negotiations over resources and issues such as access to essential services.^{27,28}

Targeted sites and participants

The study targeted the 14 tertiary care institutions with emergency departments registered in the Ministry of Health Special Registry of Health Services Providers (REPS in Spanish). The registry listed the same institutions in July 2020 and January 2021; all provided surgery and intensive care services. Those institutions are listed in online supplemental file 1.²⁹

Study design

This study includes two cross-sectional analyses integrating publicly available data using digital technologies and analytics. The study generated new knowledge of potential value when implementing evidence-informed approaches to improve accessibility and health equity. The study used updatable data to measure travel times and evaluate the effects of interventions and changes to infrastructure, service provision, traffic congestion and population. The following study methods seek to address current challenges for assessments of accessibility to health services¹⁰:

- Dynamic assessments of travel times to account for traffic variations.
- Inputs from diverse stakeholders to create an interactive platform that displays intersectoral data on dashboards so stakeholders can interpret data quickly and accurately.

- Disaggregated data to enable straightforward equity analysis of accessibility.
- Situational analysis of the accessibility to specific services for urban areas.
- An approach suitable for monitoring health equity related to accessibility.

The data for the cross-sectional analyses were obtained from the internet-based AMORE Platform (<https://www.iqartil.net/proyectoAMORE>), hosted by iQuartil SAS, an analytics company, and developed under the leadership of the principal investigator (LGC).

The AMORE Platform integrates data from:

- 2018 National Census Data for Cali, obtained from the official public databases of the Colombian National Department of Statistics (DANE in Spanish).^{22 23}
- The administrative divisions of Cali were obtained from the Colombian IDESC Geoportal; Traffic Analysis Zones (TAZ) were matched to the census blocks.^{13 30} The origin for each journey is the population-weighted centroid for the TAZ of the place of residence. Similarly, the destination is the centroid for the TAZ hosting the tertiary care emergency department with the shortest travel time.
- Google Distance Matrix API. For this baseline assessment of the Cali urban area, predicted travel times were downloaded on 3 July 2020 for the week of 6–12 July 2020, and on 27 October 2020, for the week of 23–29 November 2020. Travel times varied substantially during the COVID-19 pandemic and while it is unclear how this influenced Google Distance Matrix algorithms,³¹ empirical and anecdotal reports suggest they remained accurate.
- The 14 tertiary care institutions with an emergency department in Cali were identified using REPS.³⁰

Databases were integrated and tested between August 2020 and October 2021 using: KNIME open-source data analytics reporting and integration platform, Python programming language software (back end) and an interface (front end) developed with interactive data visualisation software Microsoft PowerBi.

Patient and public involvement

The AMORE Project Collaborative Group is diverse, with over two dozen contributors representing different stakeholders and sectors. Group members participated throughout the design, conduct and reporting of this study and the dissemination of results. The contributors and some public servants participated in the cocreation of knowledge and are listed in the Acknowledgements. These collaborators offer different governance perspectives: authorities, service providers, service users and organised civil society, including academics, advocates and experts from various fields of knowledge.^{32 33}

Data integration and output

The AMORE Platform dashboards and visualisations provide descriptive indicators using simple maps, dials, bars and data. These indicators show travel times using the shortest journeys and descriptive statistics for each urban TAZ at a given traffic congestion level. The displays for July and November can be accessed on the project's website. The AMORE Platform allows users to perform equity analyses by disaggregating sociodemographic characteristics.³⁴ The top section of the Platform ([figure 1](#)) has nine traffic congestion clusters and their representation in the week. A dial shows the share of the population within the set travel time threshold.

The middle section displays a population pyramid and maps the 14 tertiary care emergency departments, travel times and population density ([figure 1](#)). Each section of the pyramid or map can be toggled to filter populations. The choropleth maps can be expanded and rotated for a 3D display, with TAZ height representing population density (online supplemental file 2). Selecting a TAZ displays its ID, population and travel time.

Choropleth maps consist of TAZs established by MetroCali (Integrated Mass Transit System) in 2015 for the urban area and linked to the geotagged census block information, matching the population with these TAZs.¹³ The geometric matching of blocks and TAZs yielded 507 inhabited TAZs within the urban perimeter.

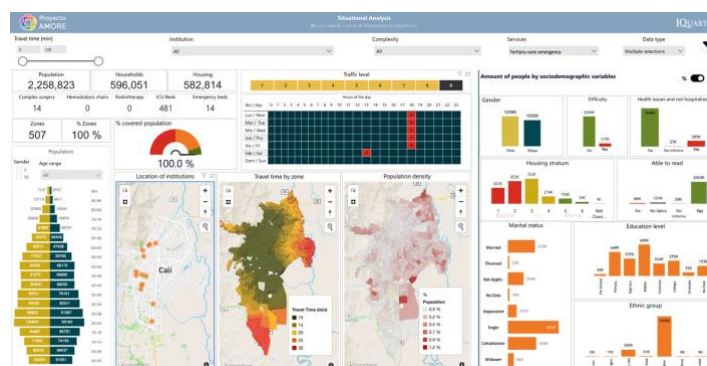


Figure 1 AMORE Platform situational analysis.

The origin–destination times were estimated from the population-adjusted geographic centroid of each TAZ to the respective centroid where each institution was located.

The Colombian census was completed through interviews with an adult for each household. Data were stored, linking it to a city block code to anonymise it. The AMORE Platform used the census microdata categorisations and, for a few variables, aggregate groups for simplification (eg, education was simplified with guidance from an expert in the Colombian education system, Psychologist Myriam Lorena Rosero Hernández, ME).

In 2019, Colombia's National Administrative Department of Statistics (DANE in Spanish) recommended adjusting the 2018 population of Cali upward by 18% from the original census data due to under-registration.^{23 35} DANE advised making further adjustments due to intercensal growth, migration and updates.^{24 36} These adjustments amounted to 28.1%, and DANE did not disaggregate the adjustment data. Therefore, 495 219 records were randomly selected and duplicated, reaching a population of 2 258 823 inhabitants, keeping the distributions. These are displayed in the AMORE Platform by toggling the census adjustment (figure 1, 'Data type').

The right section of the platform displays sociodemographic characteristics (figure 1).

The AMORE Platform displays the absolute and relative figures for the georeferenced data of inhabitants, both for the city or selected TAZs within a travel schedule figure 2. The variables integrated into the platform are listed in table 1.

Data sources and measurements

Bias

Each source is susceptible to biases and imprecision, but these are unlikely to be of a magnitude that would change conclusions. Some of the data sources and

Table 1 Census data included in the AMORE Platform dashboards and maps

Geotagged variables	Platform display
Age in completed years grouped by quinquennium (census)	Population density per TAZ
Ethnicity, self-described	Health service: tertiary care emergency departments
Health status (sick/healthy)	Absolute and relative figures of modified aggregation
Highest education level attained	Travel time thresholds (slider+choropleth heatmap)
Literacy	Travel times and population per TAZ
Marital status	Overall accessibility for filtered population
Population pyramid by gender and age	
Report of disability/physical condition	
School attendance	
Household inhabitants	
Housing inhabitants	
Housing socioeconomic stratum	
Housing type	
We used the controls listed in box 1 to conduct univariate and bivariate analyses. TAZ, traffic analysis zone.	

the timing of their updates can introduce bias. For example, the census is updated every 5 years. Since the last census in 2018, there has been a significant flow of migrants to Cali, and job losses rose during the COVID-19 pandemic.^{24 37} These developments likely make our

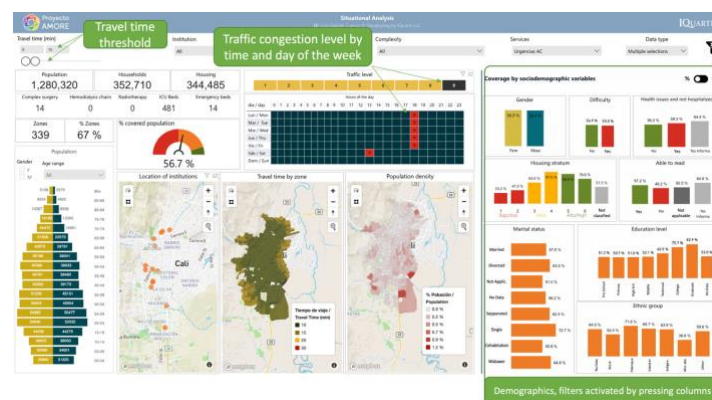


Figure 2 Situational analysis, filters and visualisations 21 November 2020.

Box 1 AMORE Platform displays resulting from integrating travel times with census data and the traffic analysis zone (TAZ) for the residence and destination health service

Variables that change according to traffic, travel time threshold and other filters.

Travel time threshold filter for the analysis.

Drop-down list with institutions that can be toggled for inactivation.

Drop-down list to select people registered by the census, the 28.1% adjustment or the adjusted census data.

Traffic levels identified with a K-means clustering algorithm.

Absolute and relative figures or each variable.

Choropleth maps organised by TAZs.

Intensive care beds data for selected institutions taken from the Special Registry of Health Services Providers (REPS).

People with accessibility for a selected time threshold and traffic level.

Blocks with accessibility for a selected time threshold.

TAZs within the time threshold by traffic level.

Household inhabitants.

Housing inhabitants.

Housing by power bill economic stratum.

results appear more favourable than they are. The census had under-registration from failed or incomplete visits, under-reporting of people living in households or people absent in each of the three times registrars visited. The estimates for migrants and intercensal growth are broad and likely unevenly distributed among the population, and no precise measurement errors are available.^{23 24}

Traffic patterns may have changed with the imposition and lifting of pandemic-related restrictions, thus altering traffic predictions. Stay-at-home orders and traffic restrictions may have changed traffic congestion, causing unusual and uneven patterns of accessibility. Google Distance Matrix API may have more accurate travel times for areas where more people travel with mobile phones and in cars.

Income categorisation is determined by the individual household electricity bill, which is graded from 1 to 6, with 6 representing the highest income households. Some homes may have been misclassified (eg, due to error or corruption) and that low-income people are living in higher income households. This is possible for relatives and domestic workers residing in high-income housing and earning minimum wages or having no income. This kind of misclassification would introduce some bias that would over-represent high-income populations.

The Colombian census recognises ethnicity, but some people likely found it difficult to choose their ethnicity. The census lacks an option for residents of white or mestizo descent, two large groups not explicitly listed on the census. Similarly, people with multiethnic parents may find it challenging to choose one ethnic category.

Traffic restrictions linked to car licence numbers affect households and neighbourhoods differently; more

affluent families are more likely to own more cars and be less affected by these measures.³⁸

To reduce data downloads, we performed a cluster analysis (using a K-means method) of the travel times on a sample of the total weekly hours. This allowed us to identify the hours of the week with similar traffic congestion levels by measuring the incremental changes against the minimum travel time. We determined that nine clusters allowed us to discriminate traffic congestion based on sensitivity analysis to represent the 168 hours of the week.

For each day and hour time band, we estimated the percentage difference between the minimum time of that trip and the travel for the time band. We calculated the average of this metric for all the journeys of the sample to obtain clusters. For example, the traffic from 18:00 to 19:00 on weekdays and from 12:00 to 14:00 on Saturdays behaves similarly for this cluster, representing the highest traffic congestion. Creating these clusters again reduces information requirements and costs.

Using hourly assessments is arbitrary; travel times could be measured every minute or second. However, more frequent checks would increase costs (ie, from data downloads, computing time, people time) by orders of magnitude without substantive changes in the conclusions. More frequent checks would thus be impractical and of little value. Details of the effects of these optimisations will be the subject of a future manuscript.

Using congestion clusters and TAZs for the 14 institutions made it possible to obtain the city estimates with a sample of 1159536 measurements downloaded from Google Distance Matrix API. The geometric matching of blocks and TAZs yielded 507 inhabited TAZs in the urban perimeter.

Populations are not evenly distributed across TAZs. We therefore adjusted TAZ geographic centroids by weighing population distribution. Because centroids had irregular shapes, population-weighted centroids could end outside the boundaries of a TAZ. This required relocating the adjusted centroid to the nearest border, potentially generating some seconds of imprecision in estimates. Similarly, using the TAZ of a hospital instead of the location of the emergency department entrance also generates imprecisions.

Traffic patterns are not homogeneous within the city or its TAZs; traffic flow patterns vary in time and direction. We therefore sorted traffic times so that cluster 9 always represented the maximum traffic congestion, cluster 1 the minimum traffic congestion and intermediate clusters were sorted accordingly. Figure 3 illustrates the clusters and variations.

The definition of an acceptable travel time threshold to reach a tertiary care emergency department is arbitrary, and we found no international standard. For this analysis, we chose a threshold of 15 min at peak-traffic congestion times that was the most frequently considered by interviewed local public servants and members of the AMORE Project Collaborative Group; it is within the thresholds found in the literature.^{39–41}

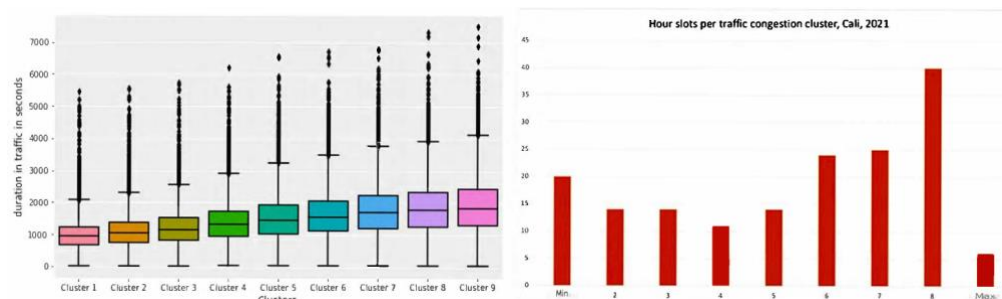


Figure 3 Travel time clusters from free-flow to peak traffic, by time and day.

Notably, the distribution of traffic levels is skewed towards heavy congestion from Monday to Saturday between 06:00 and 22:00, with the mode being cluster 8 (40/168 hours, or 24% of the week); Cali is a congested city.

RESULTS

Participants

The study included the adjusted population of 2258823 people, representing 596051 households living in 582814 housing units. The size and representation of populations are disaggregated in [table 2](#).

Most of the population is mestizo or white (83.7 %) or Afro-descendants (14.5%). Islanders and Rrom people represent less than 1% of the population. Absolute and relative figures disaggregated by sociodemographic characteristics are presented in [table 2](#).

Descriptive data

The analysis found that most of the low-income population could not reach the nearest tertiary care emergency department within 15 min during peak-traffic times, whether in July 2020 (92.3%) or November 2020 (81.4%; online supplemental file 2 and online supplemental file 3, respectively).

The analysis also shows that accessibility is a substantial barrier to low-income households with high population density and those living in peripheral TAZs, amplifying inequities.

Main results

The effects of traffic disaggregated by household income level, ethnicity, gender and age, education level, and civil status are presented in [figures 4–6](#); [table 2](#) shows differential accessibilities by housing stratum during peak and free-flow traffic hours, with the differential being more detrimental to the poorest and more affected by peak-traffic congestion.

Traffic variations and their effect

6–12 July versus 23–29 November 2020

The July travel time predictions pointed to 831982 people (36.8%) living within 15 min of travel time from tertiary care emergency services, but this increased to 1.28 million (56.7%) in November. The distribution of accessibility

when disaggregating data by income level indicated lower accessibility for the poor and those living in peripheral TAZs ([figures 4 and 5](#), and evident in online supplemental file 2 and online supplemental file 3 to those familiar with the demographic distribution of Cali). These populations also have a higher representation of minority ethnic groups and people with lower educational attainment.

[table 2](#) shows the data obtained from the AMORE Platform for the July 2020 and November 2020 assessments, which lets users explore equity considerations.

Other analyses

[Figure 6](#) shows that people living in low-income households face longer travel times and are more severely impacted by traffic congestion; they thus invest more resources in accessing services.

Myriads of analyses can be done by modifying traffic congestion clusters, travel time thresholds or toggling population groups or institutions. For pragmatic reasons, this article focused on sticking to the 15 min threshold and exploring accessibility at peak hours in more detail, which is a good scenario when planning for emergencies.

Palenque, Islanders, Rrom and indigenous people represent 0.5% of the population of Cali. Minority ethnic groups benefitted the most from the reduction in traffic congestion. The noticeable improvement among the Palenque resulted from most living in the southeastern neighbourhoods of El Morichal, El Retiro, El Vallado and Ciudad Córdoba, which fell within the 15 min threshold when traffic eased in November (see [figure 7](#)).

DISCUSSION

Main findings

The analysis shows substantial variations in access to tertiary care emergency services due to traffic congestion and the links between geographical accessibility and other social determinants of health. The two points of estimate were for early July and late November 2020, and their substantial variations stress the importance of having updatable sources.

The unusually light traffic congestion of November 2020 might have been due to the mobility restrictions associated

Table 2 Accessibility by auto within 15 min to tertiary care in July and November, Cali 2020											
15 min accessibility to the nearest tertiary care emergency service	July 2020 (%)	November 2020 (%)	Change (%)	July 2020 (#)	Nov 2020 (#)	Change (#)	Total population	%	Accessibility July (%)	Accessibility November (%)	Subgroup change (%)
	36.8	56.7	19.8	831 982	1 280 320	448 338	2 258 823		36.8	56.7	
Socioeconomic stratum											
Low	7.7	18.6	10.8	174 869	419 448	244 579	1 109 549	49.1	15.80	37.8	22.0
Middle	22.0	30.0	8.0	496 558	677 967	181 409	935 699	41.4	53.1	72.5	19.4
High	7.0	7.9	0.9	157 682	178 277	20 595	204 589	9.1	77.1	87.1	10.1
N.D.	0.1	0.2	0.1	2873	4628	1755	8986	0.4	32.0	51.5	19.5
Ethnicity											
Afro descendent	3.1	5.6	2.5	70394	126 298	55904	325 865	14.4	21.6	38.8	17.2
Rrom (nomadic)	0.0	0.0	0.0	37	53	16	102	0.0	36.3	52.0	15.7
Indigenous	0.2	0.3	0.2	3571	7103	3532	11 112	0.5	32.1	63.9	31.8
Islander/Raizal	0.0	0.0	0.0	182	251	69	382	0.0	47.6	65.7	18.1
Other (Caucasian, mestizo)	32.9	49.9	17.0	743 469	1 126 671	383 202	1 890 491	83.7	39.3	59.6	20.3
Palenque	0.0	0.0	0.0	29	176	147	245	0.0	11.8	71.8	60.0
N.D.	0.6	0.9	0.2	14 300	19 768	5468	30 626	1.4	46.7	64.5	17.9
Educational level											
Graduate degree	2.1	2.7	0.5	47 785	60 019	12 234	72 441	3.2	66.0	82.9	16.9
Bachelor's degree	7.4	9.9	2.5	166 816	223 602	56 786	295 319	13.1	56.5	75.7	19.2
Technical	4.3	6.5	2.2	97 733	147 634	49 901	244 160	10.8	40.0	60.5	20.4
Middle	8.7	14.0	5.3	196 674	316 810	120 136	608 429	26.9	32.3	52.1	19.7
High school	4.7	7.6	2.9	105 509	171 843	66 334	337 065	14.9	31.3	51.0	19.7
Primary	6.3	10.5	4.3	141 309	237 344	96 035	468 206	20.7	30.2	50.7	20.5
Preschool	0.5	0.8	0.3	11 158	18 636	7478	36 294	1.6	30.7	51.3	20.6
No data	2.9	4.6	1.7	64 998	104 432	39 434	196 909	8.7	33.0	53.0	20.0
Literacy											
Literate	33.8	51.7	17.9	764 426	1 168 883	404 457	2 043 041	90.4	37.4	57.2	19.8
No literacy	0.8	1.4	0.6	17 927	32 006	14 079	66 383	2.9	27.0	48.2	21.2
N.A.	1.6	2.7	1.1	36 401	61 180	24 779	121 140	5.4	30.0	50.5	20.5
N.D.	0.6	0.8	0.2	13 228	18 251	5023	28 259	1.3	46.8	64.6	17.8
Gender/sex											
Female	19.9	30.5	10.6	449 188	688 160	238 972	1 208 617	53.5	37.2	56.9	19.8
Male	16.9	26.2	9.3	382 794	592 160	209 366	1 050 206	46.5	36.4	56.4	19.9

Continued



Open access

Table 2 Continued

15 min accessibility to the nearest tertiary care emergency service	July 2020 (%)	November 2020 (%)	Change (%)	July 2020 (#)	Nov 2020 (#)	Change (#)	Total population	%	Accessibility July (%)	Accessibility November (%)	Subgroup change (%)
	36.8	56.7	19.8	831 982	1 280 320	448 338	2 258 823		36.8	56.7	
Civil status											
Single	13.4	20.7	7.3	303 645	468 447	164 802	821 536	36.4	37.0	57.0	20.1
Married or cohabitation	14.6	22.6	7.9	330 460	509 814	179 354	896 958	39.7	36.8	56.8	20.0
Divorced or separated	2.9	4.2	1.3	65 978	95 928	29 950	163 980	7.3	40.2	58.5	18.3
Widow	1.9	2.6	0.8	42 743	59 804	17 061	95 611	4.2	44.7	62.5	17.8
N.A.	3.4	5.7	2.3	76 821	129 370	52 549	254 492	11.3	30.2	50.8	20.6
N.D.	0.5	0.8	0.2	12 335	16 957	4 622	26 246	1.2	47.0	64.6	17.6
Age											
0–4	1.6	50.5	48.9	36 401	61 180	24 779	121 140	5.4	30.0	50.5	20.5
0–14	5.4	50.9	45.6	121 111	204 055	82 944	400 527	17.7	30.2	50.9	20.7
5–14	3.8	51.1	47.4	84 710	142 875	58 165	279 387	12.4	30.3	51.1	20.8
15–24	5.3	53.9	48.6	120 001	195 693	75 692	363 311	16.1	33.0	53.9	20.8
15–59	23.8	56.4	32.7	536 754	836 078	299 324	1 482 069	65.6	36.2	56.4	20.2
15–64	25.9	56.7	30.8	585 558	904 942	319 384	1 595 016	70.6	36.7	56.7	20.0
60+	7.7	63.8	56.1	174 117	240 187	66 070	376 227	16.7	46.3	63.8	17.6
65+	5.5	65.1	59.5	125 313	171 323	46 010	263 280	11.7	47.6	65.1	17.5
80+	1.5	69.0	67.6	33 380	44 248	10 868	64 100	2.8	52.1	69.0	17.0
	36.8	56.7	19.8	831 982	1 280 320	448 338	2 258 823				
NA, not applicable; ND, no data .											



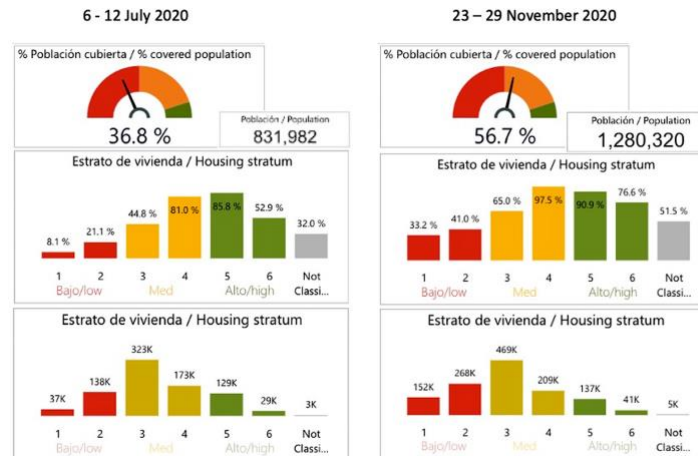


Figure 4 Accessibility by income to tertiary care comparing July and November 2020.

with the COVID-19 pandemic. Lighter traffic congestion improved accessibility for an additional 448 338 people, most living in low-income households. These people were also within the 15 min threshold ([figure 4](#)), and their location can be visualised by comparing online supplemental file 2 and online supplemental file 3. [Table 2](#) shows accessibility at peak-traffic hours disaggregated by sociodemographic characteristics relevant to equity.^{42–44}

The longest journeys were 46 min in July and November. These journeys started from densely populated, impoverished eastern neighbourhoods along the Cauca River (Aguablanca district) and sparsely populated wealthy villas in the southern edge of the city, bordering Jamundí.

Easing traffic congestion brought an additional 22% (244 579) of people in the low-income household and 19.4% (181 409) more people living in middle-income households within the 15 min threshold.

Improvements were not notably disparate among the different groups (sex, educational attainment and literacy, age and civil status). In terms of education, people with higher educational attainment (a bachelor's degree or higher) were less impacted by traffic changes (69 020 people) and those with lower educational attainment were more highly impacted (eg, 282 505 people with primary, middle, high or technical school education). The variations seemed unimpressive in relative terms but are notable in absolute numbers, considering that an

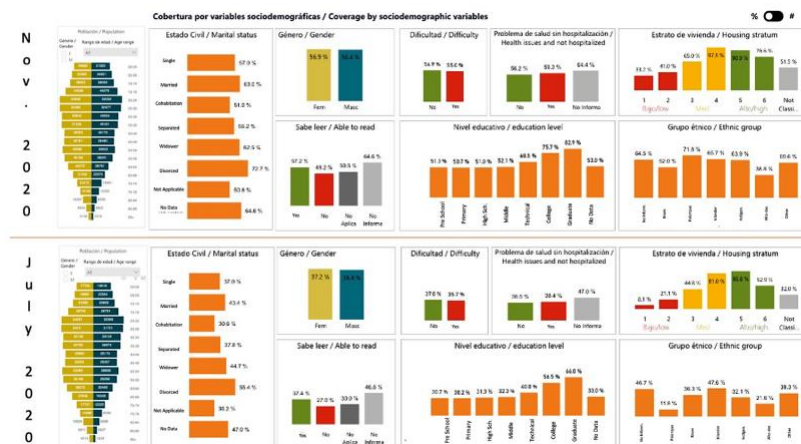


Figure 5 Accessibility by sociodemographic characteristics in July and November 2020.

Impact of traffic congestion on accessibility to tertiary care emergencies, by economic stratum of the dwelling

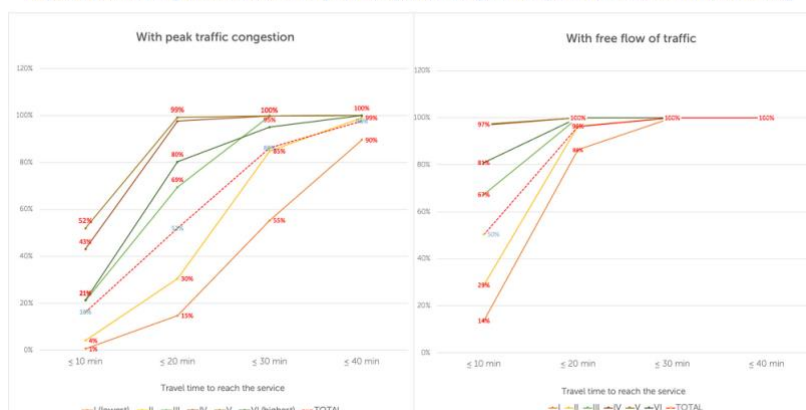


Figure 6 Impact of traffic congestion on accessibility, by economic stratum, July 2020.



Figure 7 Location of the Palenque people.

additional 332 406 people with primary, middle, high or technical school education were included as congestion eased. Variations in congestion resulted in substantial accessibility improvement, with nearly half a million more people within a 15 min accessibility threshold, almost 20% of the population.

Comparing age groups, children and the young and working age populations gained more accessibility with the changes in traffic, as the elderly tend to live closer to health services.

Variations in traffic congestion can lead to notable accessibility measurement changes among populations that concentrate around the borders of assessed travel time thresholds, as seen among the Palenque people.

Online supplemental files 2 and 3 show that tertiary care health services are far from where most of the population lives. Geospatial analysis, big data, and predictive and prescriptive analytics could inform service planning in ways that maximise accessibility if new services address these limitations.

Limitations

The AMORE Platform used data modelling and clustering to estimate travel times between the origin and destination TAZ, lowering the cost of using big data and still delivering accessibility. Operational costs are thus low, and platform updates for monitoring and evaluation are affordable. The trade-off for affordability is imprecisions in estimates. These imprecisions are more likely to affect populations living near the 15 min threshold and those further away from TAZ centroids with heavy traffic congestion. However, these imprecisions are unlikely to change the overall urban assessment.

Predicted travel times from the Google Distance Matrix API are accurate and are fed by big data from

smartphones. Other databases, such as Waze Transport SDK API, can be used to generate estimates, but these providers do not release prediction algorithms. It is thus impossible to know the magnitude and variations introduced by unforeseen events, like pandemic-related restrictions, and to estimate the impact of resulting errors or biases on estimates.

Colombian law requires hospitals to treat patients in emergencies. Modelling for this study assumed that people would resort to the hospital with the shortest travel time. However, people may go to a different hospital if they know it better, their insurer recommends it or it has a good reputation. Our estimates are thus likely optimistic.

While choropleth maps allow users to explore the travel times from a specific TAZ, panels do not reflect that a origin of a journey will not always be the place of residence. This limitation will spread differently at different times and for diverse populations.

The relevance of our findings could change if the registered tertiary care facilities changed in REPS (ie, a new institution opens, or an existing institution is reclassified as tertiary, changing the results). The interactive platform allows for prompt updates and reanalysis in response to these contingencies.

Interpretation

The AMORE Platform reveals accessibility and its health equity implications, providing new dynamic data that account for the effects of traffic. It does so more precisely and at a fraction of the costs of household surveys and origin–destination studies, providing a new tool to inform service plans, programmes and policies.

Integrating publicly available data from public sources might be a breakthrough that improves evidence-informed decisions regarding the location and provision of health services. Visualisations might help stakeholders interpret the data and agree on a common objective and metric: painting the city green by covering its entire population and offering equitable accessibility to all people.

Updating the AMORE Platform is cheaper and faster than updating other origin–destination studies; its assessments are granular and sensitive to variations and can be used to monitor and evaluate changes. In emergencies such as earthquakes, a modified platform could provide a prompt situation analysis by feeding real-time data downloads rather than predictions.

These findings suggest that with congested traffic in peak hours, most Cali residents (63%) are beyond the 15 min travel time threshold by car to the nearest tertiary care emergency department. However, this figure fell to 43% when traffic congestion eased.

Reduced accessibility is unevenly distributed and reflects the inverse care law: people who live in low-income households or have less education face longer journeys to tertiary care emergency departments. Incidentally, heavy traffic also affects people on the periphery

of Cali, including some high-income households, as congestion clogs roads they use to reach tertiary emergency care facilities.

Accessibility is one of many potential access barriers to health services and a critical one. Other factors that affect access to healthcare (eg, rights, quality or supplies) are meaningless if patients cannot reach tertiary emergency care in a crisis. Additional barriers to accessing health services (such as non-compliance with Colombian law, perceived or present quality issues, or institutional reputation) are beyond the scope of this study and merit consideration.

Researchers and planners can use data mining to optimise new tertiary care emergency services locations that maximise accessibility. Data mining could inform which existing institutions should be prioritised for an upgrade to improve accessibility or point at the optimal location for new ones, thus informing sound choices. These data are unique and provide an opportunity to enhance health services planning. Stakeholders and health equity advocates should encourage the integration of accessibility considerations in urban planning processes.

Planners and service providers wishing to combat social injustices must examine this new evidence that distance and congestion combine to exclude the most vulnerable and socioeconomically disadvantaged from critical health services. Planners and service providers must then consider bringing services closer to these populations. This new evidence and approach raise opportunities to address inequities, improve indicators and engage stakeholders in urban planning. Future studies will examine the impact of this approach. This evidence supports planning using travel time and monitoring accessibility and equity when assessing the quality of health services.^{45–47}

This situational analysis is insufficient to drive change. Integrating evidence about accessibility and equity into stakeholder and intersectoral dialogues, decision-making processes and other strategies that seek the social appropriation of knowledge by stakeholders and sectors might be catalysts for implementation.^{33 48}

This report is part of the broader AMORE Project. Future reports will explore the potential of optimising the location of up to two new emergency departments. Future studies will assess the use and appropriation of data, and the advocacy of stakeholders, including those in the AMORE Project Collaborative Group (table 3).^{10 49}

Interactive platforms can help decision makers explore different assumptions and myriads of other results of combining different thresholds and traffic levels, allowing data to speak for itself.^{18 50}

Looking ahead, identifying and proposing public policy plans and partnerships could improve health equity and bring hope to residents of Cali. These measures could also reduce social injustices, including the burden of the inverse care law that vulnerable populations pay more to access essential health services.^{4 51 52}

Table 3 Contributions by members of the AMORE Project Collaborative Group approving the manuscript

Surname	Given name	Draft writing	Revision and comments	Conceptual contributions	User perspectives	Stands by manuscript	Approved final version
Agredo Lemos	Freddy Enrique		•	•	•	•	•
Avila Rodriguez	German				•	•	•
Bula	María Olga	•	•	•	•	•	•
Concha Eastman	Alberto			•	•	•	•
Cuervo	Daniel	•	•	•		•	•
Cuervo	Luis Gabriel	•	•	•		•	•
Franco	Oscar			•		•	•
Garcia	Christian			•	•	•	•
Guerrero	Rodrigo		•	•	•	•	•
Hatcher-Roberts	Janet	•	•	•		•	•
Jaramillo	Ciro	•	•	•	•	•	•
Martínez Arámbula	Fernando Rafael			•		•	•
Martínez Herrera	Eliana	•	•	•	•	•	•
Merino Juárez	Maria Fernanda		•	•		•	•
Osorio	Lyda	•	•	•	•	•	•
Ospina	Maria B			•	•	•	•
Paredes	Gabriel		•	•		•	•
Paredes-Zapata	David		•	•	•	•	•
Pinilla	Luis Fernando	•	•	•	•	•	•
Piquero	Felipe	•	•		•	•	•
Rojas	Oscar		•		•	•	•
Rosero Hernández	Myriam			•		•	•
Tobar-Blandón	María Fernanda		•		•	•	•
Zapata Murillo	Pablo			•		•	•

Generalisability and applicability

This study is reproducible in other settings with dynamic travel time data (eg, Waze or Google Maps) and georeferenced service and population data that make situational analyses accessible. Information accuracy depends on the accuracy of sources, the modelling used to conduct searches and maintaining data that are affordable and easy to interpret.

Travel times, infrastructure and populations change. Travel times and census data may thus need to be updated, and traffic clusters may need to be adjusted.

The proposed approach highlights the dynamic nature of travel times and uses TAZs to offer a granular assessment of the city. The scale of these assessments is suitable for informing short-term or long-term policies and plans and can be periodically revised as conditions change.

Conclusions and future directions

These results test an approach to provide a situational analysis. Defining potential improvements by adding services and using data by decision makers and other

stakeholders are part of the broader AMORE Project and the subject of future reports. Travel time is a continuous variable and could be the subject of myriad analyses beyond the purpose of this study. Our aim is to demonstrate the possibility of conducting an affordable situational analysis with existing data providing information that decision makers and other stakeholders might use, something to be assessed in future studies.

The web-based platform allows users to change assumptions or variables, explore different scenarios or perform sensitivity analyses. The possibilities are numerous and include expanding the study with more bivariate and multivariate analyses that go beyond the objectives of this report.

Ethical considerations

This observational study on quality improvement for health services planning does not research human subjects. It integrates anonymised coded secondary data sources obtained from publicly available open records.^{53 54} No identifiable private information was used

in the study. Oversight of the project has been provided by the Doctoral Programme on Methodology of Biomedical Research and Public Health at the Department of Paediatrics, Obstetrics & Gynaecology and Preventative Medicine at the Universitat Autònoma de Barcelona. Contributors to this study are members of the AMORE Project Collaborative Group and public servants in their official capacity; they are listed in the acknowledgements (table 3).

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Contributors The guarantor, corresponding author and principal investigator (PI), LGC, led the project and manuscript writing and conceptualised the study with support from DC and CJ. Substantive additional contributions and editing of the report were provided by (in alphabetical order): MOB, JH-R, EM-H, LFP, FP and LO. All members of the AMORE Project Collaboration listed in table 4 provided comments, conceptual contributions or consumer perspectives. Those listed approved the manuscript, declared they stood by this research report and approved being recognised as members of the AMORE Project Collaboration.

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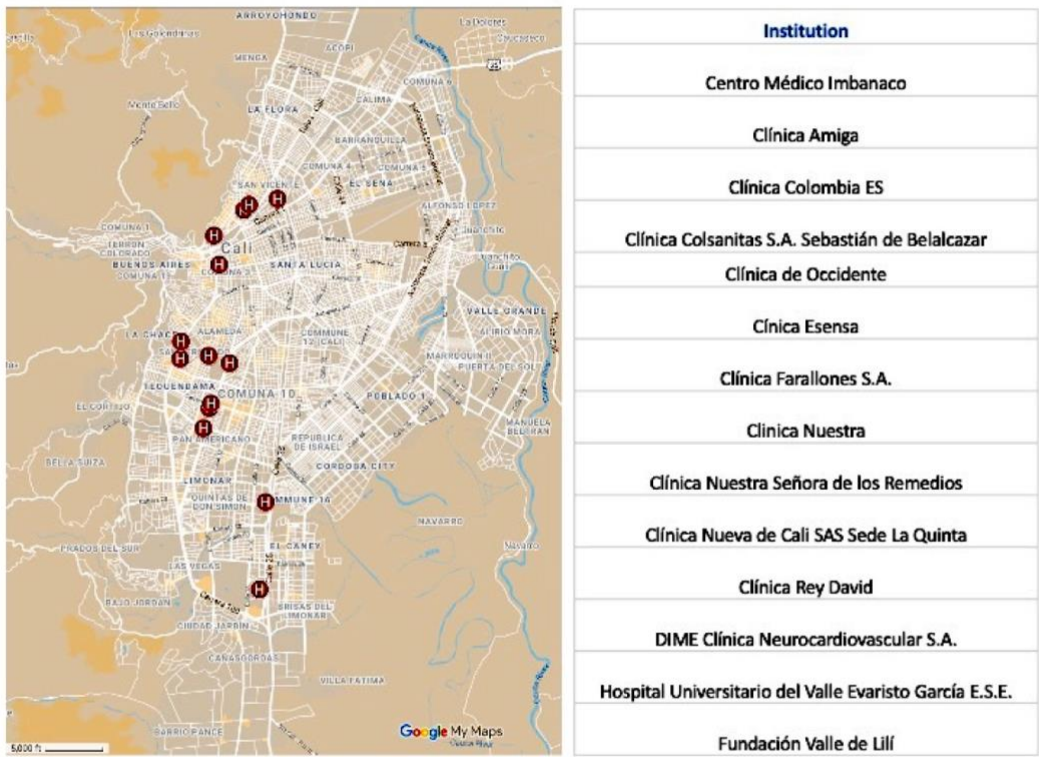
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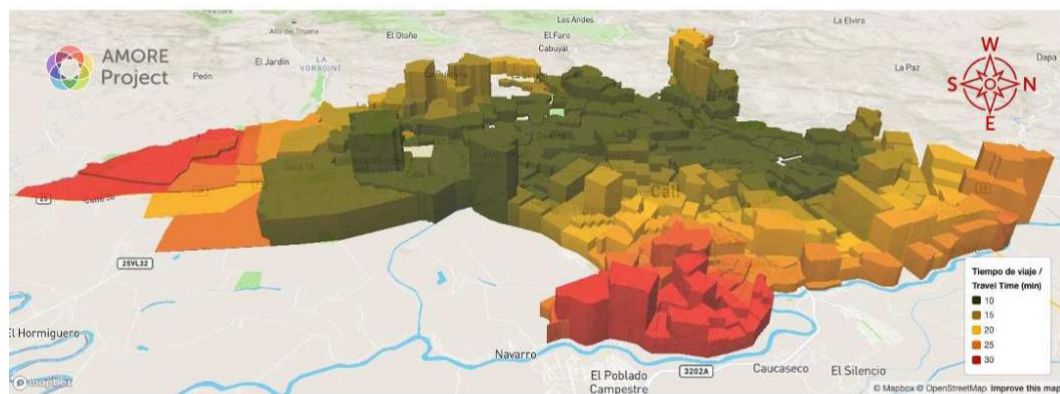
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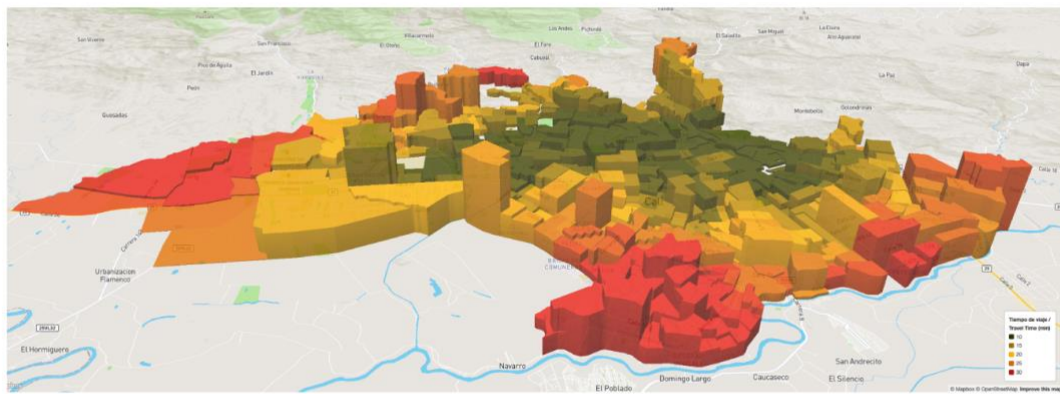
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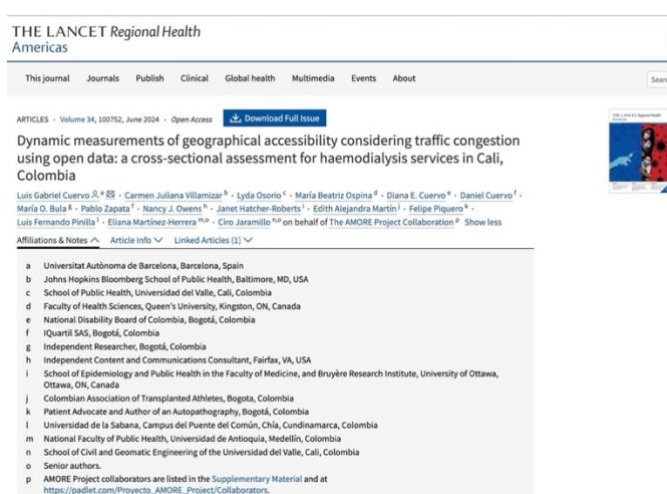


1.1.1 The Lancet Regional Health Americas – Accessibility to haemodialysis.

The second publication of the compendium was in *The Lancet – Regional Health Americas*, indexed in Scimago, with an H-index of 37 and ranked Q1 for Health Policy, Internal Medicine, Public Health, Environmental and Occupational Health. The journal has an impact factor of 7.0 and a CitScore of 8.0. By the end of 2025, it had been cited six times. The article was the Editor's Pick for the issue. It presents dynamic accessibility assessments and forecasts of improvements from the addition of new healthcare services. It identifies up to two facility locations that maximise urban accessibility in Cali, Colombia.

- Cuervo LG, Villamizar CJ, Osorio L, Ospina MB, Cuervo DE, Cuervo D, Bula MO, Zapata P, Owens NJ, Hatcher-Roberts J, Martin EA, Piquero F, Pinilla LF, Martínez-Herrera E, Jaramillo C, on behalf of the AMORE Project Collaboration. **“Dynamic Measurements of Geographical Accessibility Considering Traffic Congestion Using Open Data: A Cross-Sectional Assessment for Haemodialysis Services in Cali, Colombia.”** *The Lancet Regional Health - Americas* 34 (June 1, 2024): 100752.

<https://doi.org/10.1016/j.lana.2024.100752>



Publication 1 Situational analysis and predictions for haemodialysis and editor's pick⁸¹ (Open the file by clicking the image)

Dynamic measurements of geographical accessibility considering traffic congestion using open data: a cross-sectional assessment for haemodialysis services in Cali, Colombia



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Summary

Background Many cities with traffic congestion lack accessibility assessments accounting for traffic congestion and equity considerations but have disaggregated georeferenced municipal-level open data on health services, populations, and travel times big data. We convened a multistakeholder intersectoral collaborative group that developed a digital, web-based platform integrating open and big data to derive dynamic spatial-temporal accessibility measurements (DSTAM) for haemodialysis services. We worked with stakeholders and data scientists and considered people's places of residence, service locations, and travel time to the service with the shortest travel time. Additionally, we predicted the impacts of strategically introducing haemodialysis services where they optimise accessibility.

Methods Cross-sectional analyses of DSTAM, accounting for traffic congestion, were conducted using a web-based platform. This platform integrated traffic analysis zones, public census and health services datasets, and Google Distance Matrix API travel-time data. Predictive and prescriptive analytics identified optimal locations for new haemodialysis services and estimated improvements. Primary outcomes included the percentage of residents within a 20-min car drive of a haemodialysis service during peak and free-flow traffic congestion. Secondary outcomes focused on optimal locations to maximise accessibility with new services and potential improvements. Findings were disaggregated by sociodemographic characteristics, providing an equity perspective. The study in Cali, Colombia, used geographic and disaggregated sociodemographic data from the adjusted 2018 Colombian census. Predicted travel times were obtained for two weeks in 2020.

Findings There were substantial traffic variations. Congestion reduced accessibility, especially among marginalised groups. For 6–12 July, free-flow and peak-traffic accessibility rates were 95.2% and 45.0%, respectively. For 23–29 November, free-flow and peak traffic accessibility rates were 89.1% and 69.7%. The locations where new services would optimise accessibility had slight variation and would notably enhance accessibility and health equity.

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Interpretation Establishing haemodialysis services in targeted areas has significant potential benefits. By increasing accessibility, it would enhance urban health and equity.

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Introduction

Accessibility to essential health services advances sustainable development goals (SDGs), improves health and well-being (SDG 3), reduces inequalities (SDG 10) and makes cities and communities more sustainable (SDG 11).¹ Accessibility measures how easily and quickly people can reach a particular location, such as a health service facility. It is a dynamic attribute because it can change over time due to factors such as changes in transportation infrastructure, traffic patterns, and population density; these changes usually happen over months or years, and therefore, it is helpful to monitor geographical accessibility to health services and its impact on equity.

In cities with notable traffic congestion, accessibility fluctuates throughout the day and week due to cyclical variations in traffic congestion, and tools are needed to measure these fluctuations and find ways of reducing the impact of traffic congestion on health equity. Measuring accessibility opportunity in terms of the travel times helps us understand how long people need to travel to access healthcare and can be used to identify areas with limited accessibility to healthcare and point at solutions.^{2,3} United Nations agencies have emphasised the importance of integrating health into urban policies through participatory processes and ensuring health equity. The overarching goals involve facilitating access to essential services and ensuring no one is left behind.^{4,5}

Colombia aims to offer universal health coverage through a two-tier health services system and special regimes that cover insured and uninsured populations.^{6,7} Nonetheless, travel times and their associated direct and indirect costs represent access barriers to care. In 2019, the Colombian Constitutional Court ruled that the national health insurance program must cover transportation costs, but Colombian insurers still need to comply fully with this order.⁸

Haemodialysis is an expensive, life-saving treatment usually administered three times a week for about 4 h. Regular use and adherence usually improve the quality of life of people with end-stage renal disease (ESRD).^{9–11} Roughly three of every four people requiring kidney replacement therapy in Colombia are in haemodialysis.

There are 516 patients per million population (PMP) in haemodialysis and 103 new PMPs yearly.¹² The direct and indirect costs of frequent commutes to haemodialysis can impoverish patients and their families. Home haemodialysis is not widely available in Colombia,¹³ and travel time to haemodialysis might be associated with higher mortality rates and lower health-related quality of life.^{14,15} People in outlying areas of Cali have described the challenges they face seeking haemodialysis in video testimonies.¹⁶

A family member usually accompanies the patient to haemodialysis sessions, often missing work or the chance to seek a new job or a promotion.^{17,18} Thus the financial burden of haemodialysis on patients and family finances becomes a significant public health issue given the inextricable links between income and population health.¹⁶ Haemodialysis causes changes that can impair physical capacity and mobility, and patients need endurance training to counter these changes, but that training is yet to become a standard practice.^{19,20} Such mobility issues add to the challenges of long journeys.

DSTAM account for traffic congestion delays. Its increasing availability allows researchers to measure the impact of traffic congestion on accessibility and health equity.^{2,21–27} DSTAM can inform health services and related land-use planning from an equity perspective. In this project, DSTAM can rely on simple metrics like time-to-destination to monitor and address accessibility, health equity, and social justice factors.² Unlike most accessibility studies, which use sophisticated methods requiring specialised expertise, the AMORE Project follows knowledge translation good practices and simplified metrics and methods, allowing for a broader engagement.^{2,3,28,29} It takes a holistic approach to haemodialysis services planning by engaging a broad range of stakeholders with a person-centred strategy. This approach aims to translate integrated knowledge and deliver information that stakeholders can communicate to their peers and the public.^{3,4,30–34} Those stakeholders represent different levels of governance and bring insights relevant to haemodialysis demand (public health, demography, patients and advocates), offer (providers, patients, health systems and services planners) and the

Research in context

Evidence before this study

Haemodialysis is a costly and critical ambulatory treatment that patients with conditions like terminal renal failure require several times weekly. These patients and their families face direct and indirect commuting costs; longer travel times, which can be determined by heavy traffic congestion, are detrimental to the quality of care and strain their finances. Understanding how different sociodemographic groups are affected by commuting times to haemodialysis facilities is relevant when developing urban and health services plans. Between February 1st and June 30 2020, we searched the Web of Science Core Collection and Google Scholar, plus specialised databases including (PubMed, Lilacs, Epistemonikos, EvidenceAid, and McMaster Health Forum's Health Systems Evidence). We searched for [accessibility OR spatial analysis OR dynamic accessibility OR geographic accessibility OR spatial-temporal accessibility OR spatial analysis OR travel time OR traffic congestion] AND [health services OR hemodialysis OR haemodialysis OR radiotherapy OR urban health]. The identified and subsequent references are kept in the Collaborative AMORE Project's Zotero collection https://www.zotero.org/groups/2499307/mapas_dinamicos_y_acceso_equitativo_en_salud with dynamic accessibility references are filed in a subcollection. Our focused literature search from February to June 2020 and an independent review in 2021 showed that current assessments seldom account for traffic fluctuations, do not consider the needs of diverse stakeholders, and do not provide an equity perspective. We cite the few existing dynamic accessibility assessments focused on health services. These cater to specific technical specialists. They recommend policymakers use their results but have yet to include their perspectives in the development of the study. The importance of monitoring and measuring the alignment of urban and health agendas through participatory processes has garnered widespread recognition. It necessitates data and indicators linking traffic congestion, equity, and accessibility, that are accessible to stakeholders. Policy and technical documents, forums, and expert groups have raised and discussed these needs. Significant discussions have occurred at events such as the launch of The Lancet Series on Urban Design, Transport, and Health, along with publications like "Health and Urbanism," cited in this article. This study's protocol and its application have undergone thorough examination across various technical, academic, and collaborative setting, engaging policymakers, researchers, and experts spanning diverse disciplines, including health systems research, smart cities, public health, urban health, territorial and health services planning, healthcare quality and safety, innovations for health, and public policy and governance.

Moreover, the methodology has been showcased in innovations and data sciences competitions (https://padlet.com/Proyecto_AMORE_Project/products, shared and discussed with expert groups pursuing similar or complementary objectives. Presentations at urban health and learning networks, urban observatories, and within research communities such as UKRI-GCRF GREAT, OnTIME Consortium, CEDEUS, and IntallNC-LAC. Thus, we concluded that simplified, efficient, and dynamic accessibility measurements are needed to guide improvements to haemodialysis and other health services in heavily congested cities. Our research aims to assess haemodialysis accessibility accounting for traffic fluctuations. The study included policymakers, data scientists, and other stakeholders at every stage, from conceptualisation to planning, implementation, and reporting. The results from the study can contribute an equity perspective to the alignment of health and urban planning.

Added value of this study

This study proposes a novel approach tested in Cali, Colombia. It has significant practical implications for urban and health services planning. It exposes the intricate connections between service distribution, population, and health equity. It leverages available open data and millions of travel time measurements. Descriptive statistics, simple graphs, and cartography illustrate haemodialysis accessibility across various traffic congestion levels and different time thresholds using disaggregated housing and population data. The study provides an interactive platform that allows parameters and assumptions to be adjusted for varying traffic congestion levels. This offers tangible insights into the territorial distribution of haemodialysis services and their link to health equity. Most importantly, it points to the sectors where new services can optimise accessibility, predicting their impact and providing a clear roadmap for future planning, monitoring, and refinement.

Implications of all the available evidence

This study paves the way for future research -including implementation research, knowledge translation, and a shared narrative on accessibility to haemodialysis and other health services in cities with traffic congestion. Subsequent studies could explore adopting and utilising these data in shaping urban and health services planning, as well as the development of new accessibility and quality metrics for cities with traffic congestion. Furthermore, integrating these metrics with real-time service availability, insurance coverage, or other services needed for comprehensive treatment could be a promising avenue for further investigation. Developing this new research line and applying our findings could significantly enhance the accessibility and quality of health services in urban areas.

mobility to complete the journey between the place where the demand is initiated (residence) and the destination (haemodialysis service), adding insights about land-use, territorial analyses, smart cities, mobility, infrastructure. This brings to the process of haemodialysis services planning the actors and decision-makers representing challenges, tensions and opportunities.

This study is part of the AMORE Project, a proof-of-concept evaluating new approaches to place-based dynamic spatial-temporal accessibility measurements (DSTAM) for health services. It integrates publicly available data to deliver fast and affordable granular assessments of DSTAM for an entire city with an equity perspective.^{2,3,35,36} An earlier report assessed accessibility in urban Cali to tertiary care emergency services, which are essential to all residents.³⁷ This study assesses accessibility to haemodialysis services. It identifies the approximate 1–2 location(s) where new services would place most of the urban population of Cali within 20 min of a haemodialysis service by car, and the population in the catchment area of those locations. This study thus provides a proxy measurement and new data to inform health services planning and a strategy for reducing inequities in accessibility.³

We sought to explore: 1) What potential accessibility to haemodialysis did urban Cali dwellers have in 2020, depending on their sociodemographic characteristics? 2) Did accessibility vary according to socioeconomic status in urban Cali? 3) What improvements would result from strategically adding new haemodialysis services in 1–2 new neighbourhoods in Cali? 4) Changes in accessibility, by comparing two weeks of 2020.

This research is aligned with urban health research priorities.³⁸

Methods

Study population and setting

The rationale and methods for this study follow previously published studies from our group.^{2,3,37} This study assesses accessibility by car to the service with the shortest travel time among the 11 haemodialysis services, which together had 370 haemodialysis chairs in 2020 (Fig. 1). Cali is the third-largest city in Colombia by population and the largest in the Colombian Pacific region.

According to an international traffic scorecard, Cali was the fifth-most congested city in South America and 76th globally.⁴⁰ It has been a magnet for migration and an epicentre for social unrest in 2021 during the COVID-19 pandemic.^{41–43} Traffic congestion fluctuated widely in 2020 due to COVID-19 pandemic-related quarantines, stay-at-home orders, and traffic restrictions, such as those implemented in November.^{37,44–46}

ESRD has increased in Cali recently, affecting 128 per 100,000 people in 2020. Rates increase with age, especially after age of 30. In 2020, 1545 people



Fig. 1: Location of haemodialysis units in Cali, 2020.³⁹

underwent haemodialysis in Cali, with the vast majority being adults.^{47,48} Patients typically travel to haemodialysis appointments by car (private or for hire), with a family member. In Colombia, insurers have contracts with health-providing institutions (IPS in Spanish), and these contracts define which health services patients can access, leading to fragmented health services provision. We did not match patients with insurance and provider contracts.

About 75% of Cali households rely on the informal economy, mainly the most vulnerable. Unemployment rates in 2020 were 17.3% for men, 24% for women, 24.2% for young men (15–28 years), and 34.3% for young women. About 11.7% of the population lives in multidimensional poverty, and 82.2% of urban Cali residents have some health insurance.^{49,50}

To fulfil its constitutional and legal mandates, Cali's Territorial Health Plan has among its strategic objectives to manage and supervise the provision of health services for all its population.⁵¹

Targeted sites/participants

We identified all 11 haemodialysis services in Cali using the Ministry of Health Special Registry of Health Services Providers (REPS in Spanish), which remained unchanged between July 2020 and January 2021. These services are concentrated along a corridor in the north-central part of

Cali, following the major street, Calle Quinta, as indicated in Fig. 1.³⁰ Typically, haemodialysis patients in Cali need to visit haemodialysis centres as home-based haemodialysis options are limited.

Study design

We conducted two cross-sectional analyses by integrating public data sources in the web-based AMORE Platform, which displays DSTAM for each Traffic Analysis Zone (TAZ) to the TAZ hosting the haemodialysis services with the shortest travel time. TAZs are

geographic units commonly used in transportation planning and are usually built on census blocks.³¹ Travel times are typically short within a TAZ, but populations are not evenly distributed in TAZs. Therefore, travel times from each of 507 TAZs in Cali were measured from the population-adjusted geometric centroids.³¹ The 11 haemodialysis services in Cali are concentrated in six TAZs.

Data for the cross-sectional analyses was obtained from the web-based AMORE Platform (Figs. 2 and 3), hosted by iQuartil SAS and developed under the



Fig. 2: AMORE Platform interfaces with situational and predictive analyses, 6–12 July 2020.^{39,51}

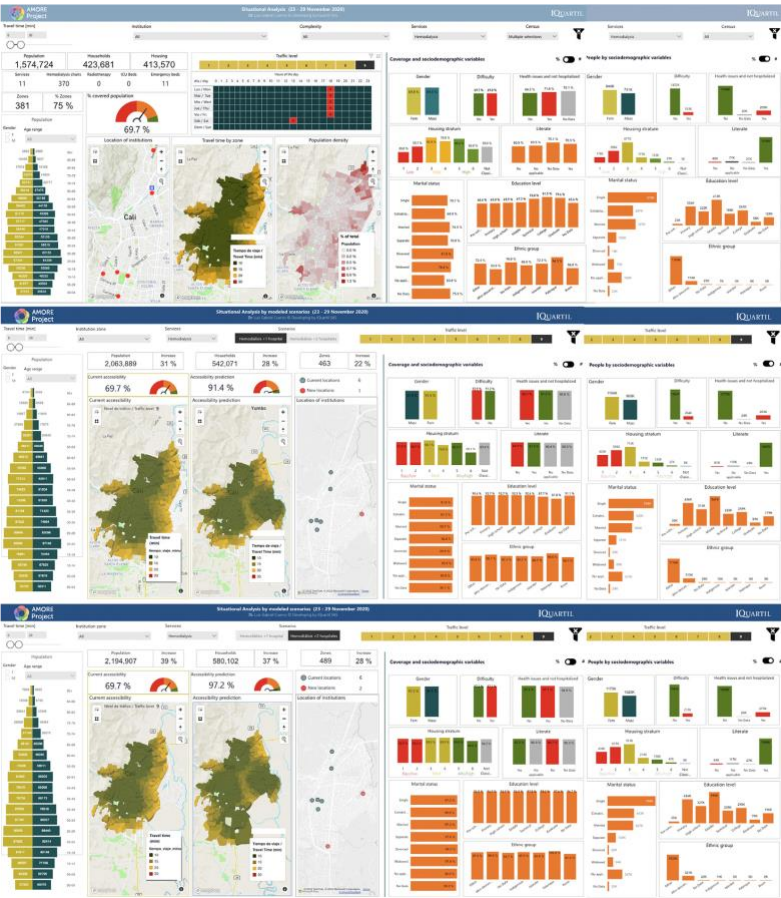


Fig. 3: AMORE Platform interfaces with situational and predictive analyses, 23–29 Nov 2020.^{38,51}

leadership of the principal investigator (LGC) and the lead data scientist (DC)^{54,55}. The AMORE Platform is constructed by integrating the following data sources:

- 2018 National Census Data for Cali, obtained from the official public databases of the Colombian Na-

tional Department of Statistics (DANE in Spanish), and adjusted to 2020.^{1,56,57}

- The administrative divisions of Cali were obtained from government sources: the IDESC Geoportal, Traffic Analysis Zones (TAZs), and census block sectors.^{58,59}
- Google's Distance Matrix API. For this test case assessment of urban Cali, data were downloaded on July 3, for the week of 6–12 July 2021. Predicted times were downloaded on 27 October for the week of 23–29 November 2020.⁶⁰

⁵⁴The AMORE Platform can be accessed from www.iqartil.net/project-amore-ingles



Fig. 4: Characteristic accessibility during day hours, traffic congestion level.

- The 11 haemodialysis services in Cali were identified using the REPS registry.³⁹ These services were in six TAZs, with one TAZ hosting four services and another TAZ hosting three.

Data for this case study were a subset of the data used by the AMORE Project to measure accessibility to 30 health services: 14 tertiary care emergency departments, 11 haemodialysis services, and five radiotherapy services. These 30 services were in 15 TAZs, with one TAZ hosting seven services, another TAZ four, six TAZ hosting two, and seven hosting a single service. Had the project focused on haemodialysis only, the eleven services would have been studied by assessing travel times to six TAZs.⁷

Measuring DSTAM for the three types of services (tertiary care emergencies, haemodialysis, and radiotherapy), using traffic congestion clusters and TAZs brought efficiencies and reduced travel time data download cost and complexity. Measurements were reduced from 43.1 million data points (507 origins to 506 destinations for 168 h weekly) to a sample of 68,445 (507 origins to 15 destinations for 9 traffic congestion clusters) for each week analysed.^{3,37} Using predictive analytics based on the sample, an estimated 2.3 million travel times (507 origins to 506 destinations in 9 traffic congestion clusters) was assessed for each week analysed. The efficiencies introduced by clustering travel times and using TAZ and predictive modelling reduced data downloads an estimated 630-fold. Measurement weeks were chosen out of interest in exploring accessibility behaviour during the COVID-19 pandemic and opportunity; we had everything in place to complete the data downloads, update the platform, and validate the data. Both assessments were completed in weeks with no holidays.

Variables for study outcomes

The main study outcome was the proportion of urban dwellers likely to reach a haemodialysis service within

20 min by car. We set a 20-min travel-time threshold to predict the potential impact of adding new services in one or two strategic locations to optimise accessibility.³ Data were disaggregated by age, self-reported sex, education level attained, literacy, marital status, and household economic stratum based on electricity bill stratification. Other study outcomes included accessibility measured at 10-min intervals, by household economic stratification. Additional information can be obtained through the web-based AMORE Platform, where readers can explore scenarios by adjusting parameters.^{30,35,61}

Travel-time thresholds were based on expert advice from AMORE Project collaborative group contributors, including patient advocates. We found no international standards and only assessed travel time by car (private and for hire), which will likely be unevenly distributed across socioeconomic groups.

Data representing primary outcomes are displayed using graphs, tables, and colour-coded choropleth maps with the isochrones of the cumulative opportunities for accessibility, presenting travel times and population density for each TAZ.^{35,36} For the predictive and prescriptive analyses, the one or two TAZs where new services would optimise accessibility were identified, and results were disaggregated by sociodemographic characteristics. The web-based platform also displays this data as colour-coded choropleth maps that can be rotated to provide a 3D perspective (Figs. 4–6), with each choropleth representing a TAZ and their height representing its population density. These maps reveal the relationship between population density and geographic location with travel times. The colour code should help stakeholders and sector leaders agree on a common goal, such as “painting the city green” by putting all people within a 20-min travel-time threshold from a service.⁶²

Traffic clusters range from free-flow (level 1) to peak traffic (level 9). Household socioeconomic stratification in Colombia has an incremental range from 1 to 6, with

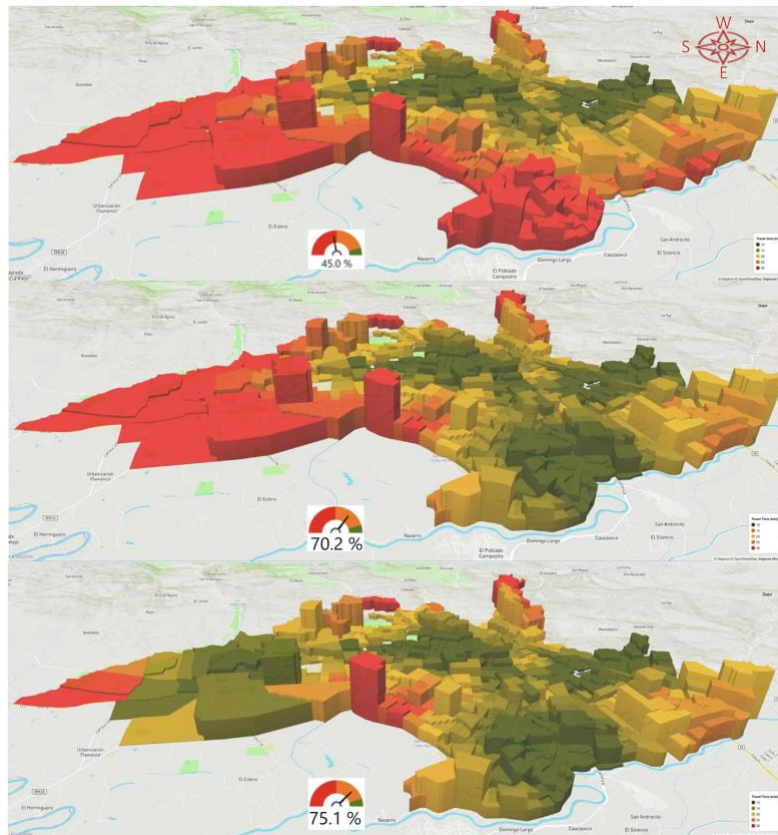


Fig. 5: Predicted accessibility with new services in selected TAZs, 6–12 July 2020.

six representing the highest-income household group. Household socioeconomic stratum was categorised into Low (levels 1 and 2), middle (3 and 4), and high (5 and 6). Earlier publications have described the definition of traffic levels and subgroup variation measurement.^{3,37,53} The platform disaggregates data by education, ethnicity, self-reported sex, age, and other sociodemographic variables. Sociodemographic characteristics, TAZs, travel times, traffic levels, and institutions can be filtered and combined for analysis.

Role of the funding source

The authors have not declared a specific grant for this research from any funding agency in public, commercial or not-for-profit sectors.

Results

Cali has substantial traffic congestion and remains congested through most of the day and evening, even on weekends. Traffic level 8, the second highest, accounts for 40/168 (24%) hours of the week (Fig. 4). Traffic clusters are skewed, with most activity hours having high-traffic congestion levels.¹⁷

Figs. 2 and 3 are screenshots from AMORE Platform interfaces that display the variables and disaggregated data for the situational and predictive analyses for the July and November assessments. These analyses include baseline data and estimate accessibility after adding services in one or two additional TAZs.

Figs. 5 and 6, illustrate the impact of traffic congestion on accessibility under assessed and predicted

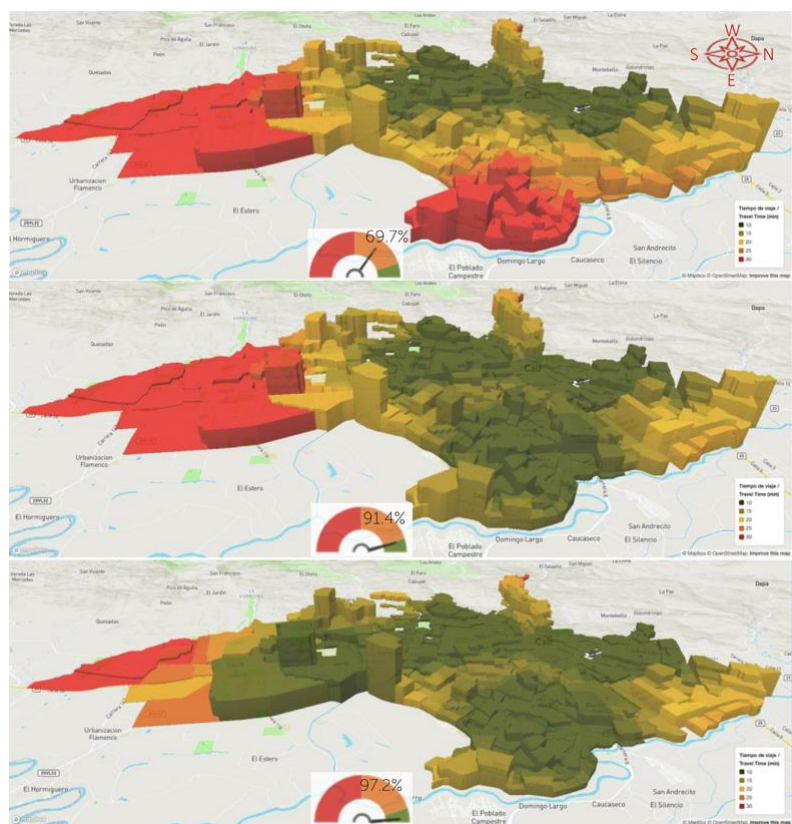


Fig. 6: Predicted accessibility with new services in selected TAZs, 23–29 November 2020.

scenarios. These results point to the locations where new services would maximise urban accessibility and provide overall and disaggregated estimates and variations for the July and November assessments.

Population characteristics are presented in Table 1. About half of Cali residents live in low-income housing, 40% live in middle-income households, and about 9% live in high-income housing, including live-in domestic workers. The southern end of Cali is inhabited mainly by high-income households living in villas. The choropleth map shows that most of the population and the most densely populated areas are towards the periphery of Cali and far from haemodialysis services (Fig. 7). Travel-time comparisons between 6 and 12 July and 23–29 November 2020 show that traffic was notably lighter in November,

when COVID-19 traffic restrictions were in place. The effect of these measures varied throughout city sectors (Figs. 5 and 6).

The images and data revealed that services are concentrated, and most of the population incurs long journeys, particularly the poorest and those from minority ethnic groups (Supplemental File 1, Table 1).

Placement of new services to optimise equitable accessibility

The optimal location for maximising accessibility changed between neighbouring TAZs between July and November but remained close and within minutes. For July, the best TAZ was in the Alirio Mora Beltrán neighbourhood; for November, it was in the neighbouring Marroquin III TAZ. Both TAZs are

Situational analysis 20 min accessibility to the nearest hemodialysis service (Population)	July 2020	November 2020	Variation	Total population	%	Accessibility july	Accessibility november	Subgroup variation
	1,017,011	1,574,724	557,713	2,258,823		45.0%	69.7%	
Socio-economic stratum								
Low	221,296	568,115	346,819	1,109,549	49.1%	19.9%	51.2%	31.3%
Middle	645,076	841,224	196,148	935,699	41.4%	68.9%	89.9%	21.0%
High	147,229	160,082	12,853	204,589	9.1%	72.0%	78.2%	6.3%
N.D.	3410	5303	1893	8986	0.4%	37.9%	59.0%	21.1%
Ethnicity								
Afrodescendent	85,481	174,224	88,743	325,865	14.4%	26.2%	53.5%	27.2%
Rrom (nomadic)	40	58	18	102	0.0%	39.2%	56.9%	17.6%
Indigenous	4339	7394	3055	11,112	0.5%	39.0%	66.5%	27.5%
Islander/Raizal	214	276	62	382	0.0%	56.0%	72.3%	16.2%
Other (Caucasian, Mestizo)	910,535	1,369,069	458,534	1,890,491	83.7%	48.2%	72.4%	24.3%
Palenque	41	231	190	245	0.0%	16.7%	94.3%	77.6%
N.D.	16,361	23,472	7111	30,626	1.4%	53.4%	76.6%	23.2%
Educational level								
Graduate degree	48,919	57,641	8722	72,441	3.2%	67.5%	79.6%	12.0%
Bachelor's Degree	187,250	240,652	53,402	295,319	13.1%	63.4%	81.5%	18.1%
Technical	123,846	187,591	63,745	244,160	10.8%	50.7%	76.8%	26.1%
Middle	254,015	409,594	155,579	608,429	26.9%	41.7%	67.3%	25.6%
High School	132,875	222,293	89,418	337,065	14.9%	39.4%	65.9%	26.5%
Primary	178,303	304,450	126,147	468,206	20.7%	38.1%	65.0%	26.9%
Pre-school	13,559	23,360	9801	36,294	1.6%	37.4%	64.4%	27.0%
No data	78,244	129,143	50,899	196,909	8.7%	39.7%	65.6%	25.8%
Literacy								
Literate	935,369	1,436,134	500,765	2,043,041	90.4%	45.8%	70.3%	24.5%
No literacy	21,864	40,417	18,553	66,383	2.9%	32.9%	60.9%	27.9%
N.A.	44,609	76,938	32,329	121,140	5.4%	36.8%	63.5%	26.7%
N.D.	15,169	21,235	6066	28,259	1.3%	53.7%	75.1%	21.5%
Gender/Sex								
Fem	547,601	844,077	296,476	1,208,617	53.5%	45.3%	69.8%	24.5%
Masc	469,410	730,647	261,237	1,050,206	46.5%	44.7%	69.6%	24.9%
Civil status								
Single	370,444	575,999	205,555	821,536	36.4%	45.1%	70.1%	25.0%
Married or cohabitation	403,517	624,355	220,838	896,958	39.7%	45.0%	69.6%	24.6%
Divorced or separated	81,711	118,628	36,917	163,980	7.3%	49.8%	72.3%	22.5%
Widow	52,705	73,457	20,752	95,611	4.2%	55.1%	76.8%	21.7%
N.A.	94,566	162,468	67,902	254,492	11.3%	37.2%	63.8%	26.7%
N.D.	14,068	19,817	5749	26,246	1.2%	53.6%	75.5%	21.9%
Age								
0-4	44,609	76,938	32,329	121,140	5.4%	36.8%	63.5%	26.7%
0-14	150,093	256,909	106,816	400,527	17.7%	37.5%	64.1%	26.7%
5-14	105,484	179,971	74,487	279,387	12.4%	37.8%	64.4%	26.7%
15-24	147,838	242,147	94,309	363,311	16.1%	40.7%	66.7%	26.0%
15-59	657,107	1,027,559	370,452	1,482,069	65.6%	44.3%	69.3%	25.0%
15-64	716,344	1,111,425	395,081	1,595,016	70.6%	44.9%	69.7%	24.8%
60+	209,811	290,256	80,445	376,227	16.7%	55.8%	77.1%	21.4%
65+	150,574	206,390	55,816	263,280	11.7%	57.2%	78.4%	21.2%
80+	40,103	52,080	11,977	64,100	2.8%	62.6%	81.2%	18.7%
Italics are used to show the difference/variation between figures on columns compared (located to the left).								
Table 1: 20-minute accessibility to haemodialysis in Cali by socio-demographic group.								

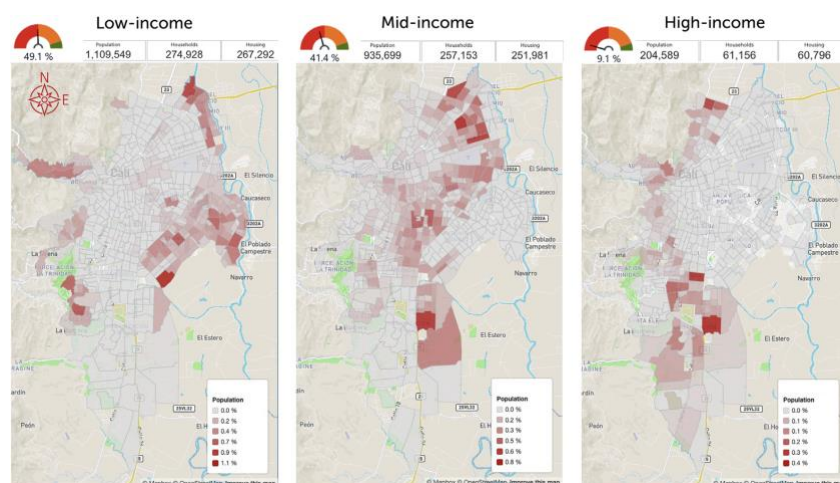


Fig. 7: Housing distribution by socioeconomic stratification, Cali.

in the eastern Agua Blanca district (Fig. 8). If services were added in two TAZs, the TAZ initially identified would remain the same in the independent predictions. The second recommended TAZ was for Parcelaciones del Pance in July and San Joaquín in November; these southern neighbourhoods are adjacent (Fig. 8).

Adding new haemodialysis service(s) to the recommended locations — in Alirio Mora Beltrán or Marroquín III TAZ in the eastern district of Agua Blanca, with access to all patients — would greatly improve accessibility for the entire city (Tables 2 and 3; Figs. 5 and 6). In this scenario, we estimated that accessibility rose from 1,017,011 (45.0%) to 1,585,437 (70.2%) for July and from 1,574,724 (69.7%) to 2,063,889 (91.4%) for November 2020. These results levelled accessibility specifically by benefiting the lowest-income residents of Cali. For example, in the July estimates, accessibility for the lowest-income group (i.e., stratum 1) rose from 51,866 (11.4%) to 296,298 (64.9%) (Fig. 9). Populations living in the southernmost high-income suburban areas benefited the least from the new service.

Additionally adding services in the southern Pance neighbourhood would reduce differences for most subgroups, raising urban accessibility to 1,696,205 (75.1%) in July and 2,194,907 (97.2%) in November. Both results represent dramatic improvements over baseline assessments (Tables 2 and 3; Figs. 5 and 6).

Accessibility improvements seen between July and November added 557,713 people to the 20-min threshold in November, primarily benefitting low- and

middle-income populations. Accessibility during peak traffic times rose 31.3% for low-income households (19.9%–51.2%) and 21.0% for middle-income households (68.9%–89.9%). Accessibility for high-income households rose just 6.2% (from 72.0% to 78.2%), perhaps because most families live close to services or in south-end villas that will still face long trips.

Subgroup improvements by other sociodemographic characteristics varied between 18% and 29%, with two exceptions. First, accessibility for people with graduate degrees rose 13.2%, reflecting November traffic restrictions and overlap in geographic distribution with high-income households. Second, accessibility rose 79.6% for the small Palenque people population concentrating around a cluster of TAZs.³⁷

Choropleth maps show that offering haemodialysis in the eastern district of Agua Blanca would make haemodialysis accessible to densely populated areas of the city. These additions would nearly double overall urban accessibility and level accessibility rates in sociodemographic groups, reducing most inequities (Figs. 2 and 3).

The 10-min interval assessments by housing socioeconomic stratum also revealed links between income and accessibility, except for the highest-income households living in south-end villas. For these households, accessibility would only improve if services were added in the thinly populated south end of the city. Differences between income groups were noticeable throughout and worsened with traffic congestion. Adding services in the proposed TAZs reduced inequities even though these persisted for the shorter 10-min journeys (Fig. 9).

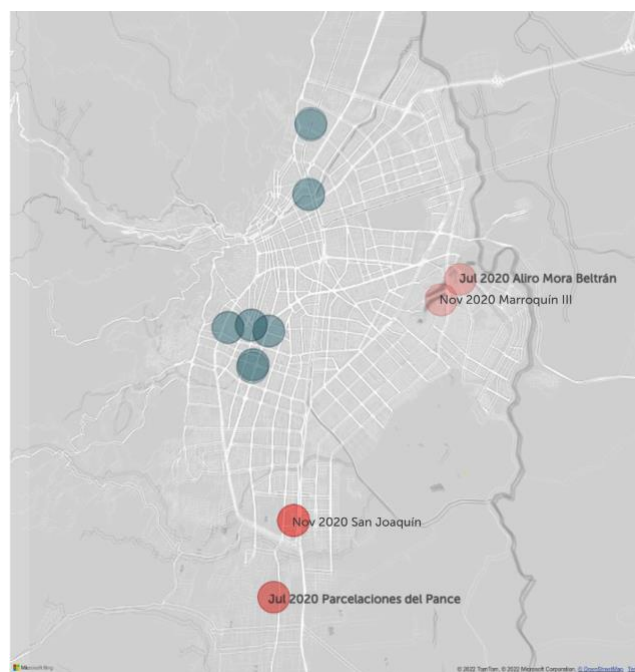


Fig. 8: The predicted 1-2 TAZs where new services optimise accessibility.

The analysis found that during peak traffic congestion and at most hours of the day (traffic levels 8 and 9), most people in the lowest-income stratum could not reach a haemodialysis service within 20 min. This was true in both the July and November assessments (11.4% and 39.6%, respectively) (Figs. 2, 3 and 9).

Data indicates that accessibility is an access barrier for low-income households, specifically in areas with high population density and outlying urban sectors (Supplemental File 1).

Table 2 (absolute figures) and Table 3 (relative subgroup proportions) provide data for the predicted accessibility to the haemodialysis service with the shortest travel times.

The 20-min threshold used in this study was deemed sound and appropriate for context by collaborative group members, including patient representatives. We found no benchmarks for travel times to haemodialysis. Time is a continuous variable; thus, an arbitrary threshold was chosen. An interactive interface enables stakeholders, including decision-makers, to test different assumptions and variables, assess the

resulting data, draw conclusions and challenge current thinking.³⁰

The haemodialysis sections of the AMORE Platform will be available at <https://www.iquartil.net/proyectoAMORE/> for at least two years from the date of this publication.

Discussion

The collaborative efforts within the AMORE Project are directed towards addressing the imperative for comprehensive methodologies that integrate health considerations into urban and territorial planning, particularly in urban settings characterised by heightened health inequities exacerbated by traffic congestion. The primary focus is on rectifying two notable deficiencies identified in existing studies: (1) the failure to systematically measure the impact of traffic congestion levels on both health equity and accessibility,^{23,28,34-43} and (2) the prevalent issue of insufficiently comprehending the intricate dynamics across interest groups that play a pivotal role in shaping health services planning and policies, resulting in a lack

Predicted 20 min accessibility to the nearest hemodialysis service, by subgroup	Population July 2020	Add 1 service	Variation	Add 2 services	Variation	Benefit of the second service	Population November 2020	Add 1 service	Variation +1 service November	Add 2 services	Variation +2 serv. november vs baseline	Benefit of the second service
	1,017,011	1,585,437	568,426	1,696,205	679,194	110,768	1,574,724	2,063,889	489,165	2,194,907	620,183	131,018
Socio-economic stratum												
Low	221,296	692,535	471,239	708,285	486,989	15,750	568,115	1,012,179	444,064	1,054,841	486,726	42,662
Middle	645,076	738,967	93,891	787,189	142,113	48,222	841,224	883,232	42,008	934,581	93,357	51,349
High	147,229	147,714	485	194,064	46,835	46,350	160,082	160,448	366	197,011	36,929	36,563
N.D.	3410	6221	2811	6667	3257	446	5303	8030	2727	8474	3171	444
Ethnicity												
Afrodescendent	85,481	226,665	141,184	235,681	150,200	9016	174,224	309,773	135,549	320,945	146,721	11,172
Rrom (nomadic)	40	70	30	75	35	5	58	88	30	93	35	5
Indigenous	4339	7093	2754	7661	3322	568	7394	10,023	2629	10,830	3436	807
Islander/Raizal	214	287	73	308	94	21	276	339	63	366	90	27
Other (Caucasian, Mestizo)	910,535	1,329,587	419,052	1,429,331	518,796	99,744	1,369,069	1,715,776	346,707	1,833,419	464,350	117,643
Palenque	41	58	17	59	18	1	231	244	13	245	14	1
N.D.	16,361	21,677	5316	23,090	6729	1413	23,472	27,646	4174	29,009	5537	1363
Educational level												
Graduate degree	48,919	51,673	2754	64,274	15,355	12,601	57,641	59,250	1609	70,683	13,042	11,433
Bachelor's degree	187,250	214,500	27,250	246,213	58,963	31,713	240,652	259,026	18,374	290,113	49,461	31,087
Technical	123,846	173,029	49,183	183,949	60,103	10,920	187,591	225,703	38,112	238,756	51,165	13,053
Middle	254,015	429,219	175,204	449,999	195,984	20,780	409,594	561,317	151,723	589,778	180,184	28,461
High School	132,875	234,812	101,937	245,256	112,381	10,444	222,293	312,505	90,212	326,680	104,387	14,175
Primary	178,303	323,554	145,251	337,279	158,976	13,725	304,450	433,804	129,354	453,532	149,082	19,728
Pre-school	13,559	24,185	10,626	25,912	12,353	1727	23,360	32,893	9533	35,018	11,658	2125
No data	78,244	134,465	56,221	143,323	65,079	8858	129,143	179,391	50,248	190,347	61,204	10,956
Literacy												
Literate	935,369	1,439,178	503,809	1,540,840	605,471	101,662	1,436,134	1,867,076	430,942	1,986,355	550,221	119,279
No literacy	21,864	44,390	22,526	46,272	24,408	1882	40,417	61,347	20,930	64,213	23,796	2866
N.A.	44,609	81,605	36,996	87,318	42,709	5713	76,938	110,033	33,095	117,422	40,484	7389
N.D.	15,169	20,264	5095	21,775	6606	1511	21,235	25,433	4198	26,917	5682	1484
Gender/Sex												
Fem	547,601	849,850	302,249	910,080	362,479	60,230	844,077	1,104,162	260,085	1,175,110	331,033	70,948
Masc	469,410	735,587	266,177	786,125	316,715	50,538	730,647	959,727	229,080	1,019,797	289,150	60,070
Civil status												
Single	370,444	576,988	206,544	615,450	245,006	38,462	575,999	754,020	178,021	799,355	223,356	45,335
Married or cohabitation	403,517	625,534	222,017	673,554	270,037	48,020	624,355	813,993	189,638	870,343	245,988	56,350
Divorced or separated	81,711	120,329	38,618	127,626	45,915	7297	118,628	151,450	32,822	160,193	41,565	8743
Widow	52,705	2171	-50,534	75,848	23,143	73,677	73,457	89,402	15,945	93,550	20,093	4148
N.A.	94,566	171,688	77,122	183,663	89,097	11,975	162,468	231,388	68,920	246,543	84,075	15,155
N.D.	14,068	18,727	4659	20,064	5996	1337	19,817	23,636	3819	24,923	5106	1287
Age												
0-4	44,609	81,605	36,996	87,318	42,709	5713	76,938	110,033	33,095	117,422	40,484	7389
0-14	150,093	270,764	120,671	289,257	139,164	18,493	256,909	364,761	107,852	387,896	130,987	23,135
5-14	105,484	189,159	83,675	201,939	96,455	12,780	179,971	254,728	74,757	270,474	90,503	15,746
15-24	147,838	249,309	101,471	266,631	118,793	17,322	242,147	331,487	89,340	352,301	110,154	20,814
15-59	657,107	1,031,825	374,718	1,696,205	1,039,098	664,380	1,027,559	1,349,753	322,194	1,439,686	412,127	89,933
15-64	716,344	1,115,142	398,798	1,196,118	479,774	80,976	1,111,425	1,453,704	342,279	1,549,551	438,126	95,847
60+	209,811	282,848	73,037	299,656	89,845	16,808	290,256	349,375	59,119	367,325	77,069	17,950
65+	150,574	199,531	48,957	210,830	60,256	11,299	206,390	245,424	39,034	257,460	51,070	12,036
80+	40,103	50,570	10,467	52,893	12,790	2323	52,080	60,472	8392	62,987	10,907	2515
Italics are for the calculations made on differences when adding one or two services. Columns in non-italic represent the raw data from the platform.												
Table 2: Predicted accessibility to the haemodialysis service with the shortest travel times (absolute figures).												

Articles

Predicted 20 min accessibility to the nearest hemodialysis service, by subgroup (%)	July 2020 (% subgroup)	Add 1 service	Variation	Add 2 services	Variation adding 2 services	Benefit of the second service	Nov 2020 (%)	Add 1 service	Variation +1 service november	Add 2 services	Variation +2 serv. november vs baseline	Benefit of the second service	Subgroup's population
Socio-economic stratum													
Low	19.9%	62.4%	42.5%	63.8%	43.9%	1.4%	51.2%	91.2%	40.0%	95.1%	43.9%	3.8%	1,109,549
Middle	68.9%	79.0%	10.0%	84.1%	15.2%	5.2%	89.9%	94.4%	4.5%	99.9%	10.0%	5.5%	935,699
High	72.0%	72.2%	0.2%	94.9%	22.9%	22.7%	78.2%	78.4%	0.2%	96.3%	18.1%	17.9%	204,589
N.D.	37.9%	69.2%	31.3%	74.2%	36.2%	5.0%	59.0%	89.4%	30.3%	94.3%	35.3%	4.9%	8986
Ethnicity													
Afrodescendent	26.2%	69.6%	43.3%	72.3%	46.1%	2.8%	53.5%	95.1%	41.6%	98.5%	45.0%	3.4%	325,865
Rrom (nomadic)	39.2%	68.6%	29.4%	73.5%	34.3%	4.9%	56.9%	86.3%	29.4%	91.2%	34.3%	4.9%	102
Indigenous	39.0%	63.8%	24.8%	68.9%	29.9%	5.1%	66.5%	90.2%	23.7%	97.5%	30.9%	7.3%	11,112
Islander/Raizal	56.0%	75.1%	19.1%	80.6%	24.6%	5.5%	72.3%	88.7%	16.5%	95.8%	23.6%	7.1%	382
Other (Caucasian, Mestizo)	48.2%	70.3%	22.2%	75.6%	27.4%	5.3%	72.4%	90.8%	18.3%	97.0%	24.6%	6.2%	1,890,491
Palenque	16.7%	23.7%	6.9%	24.1%	7.3%	0.4%	94.3%	99.6%	5.3%	100.0%	5.7%	0.4%	245
N.D.	53.4%	70.8%	17.4%	75.4%	22.0%	4.6%	76.6%	90.3%	13.6%	94.7%	18.1%	4.5%	30,626
Educational level													
Graduate degree	67.5%	71.3%	3.8%	88.7%	21.2%	17.4%	79.6%	81.8%	2.2%	97.6%	18.0%	15.8%	72,441
Bachelor Degree	63.4%	72.6%	9.2%	83.4%	20.0%	10.7%	81.5%	87.7%	6.2%	98.2%	16.7%	10.5%	295,319
Technical	50.7%	70.9%	20.1%	75.3%	24.6%	4.5%	76.8%	92.4%	15.6%	97.8%	21.0%	5.3%	244,160
Middle	41.7%	70.5%	28.8%	74.0%	32.2%	3.4%	67.3%	92.3%	24.9%	96.9%	29.6%	4.7%	608,429
High School	39.4%	69.7%	30.2%	72.8%	33.3%	3.1%	65.9%	92.7%	26.8%	96.9%	31.0%	4.2%	337,065
Primary	38.1%	69.1%	31.0%	72.0%	34.0%	2.9%	65.0%	92.7%	27.6%	96.9%	31.8%	4.2%	468,206
Pre-school	37.4%	66.6%	29.3%	71.4%	34.0%	4.8%	64.4%	90.6%	26.3%	96.5%	32.1%	5.9%	36,294
No data	39.7%	68.3%	28.6%	72.8%	33.1%	4.5%	65.6%	91.1%	25.5%	96.7%	31.1%	5.6%	196,909
Literacy													
Literate	45.8%	70.4%	24.7%	75.4%	29.6%	5.0%	70.3%	91.4%	21.1%	97.2%	26.9%	5.8%	2,043,041
No literacy	32.9%	66.9%	33.9%	69.7%	36.8%	2.8%	60.9%	92.4%	31.5%	96.7%	35.8%	4.3%	66,383
N.A.	36.8%	67.4%	30.5%	72.1%	35.3%	4.7%	63.5%	90.8%	27.3%	96.9%	33.4%	6.1%	121,140
N.D.	53.7%	71.7%	18.0%	77.1%	23.4%	5.3%	75.1%	90.0%	14.9%	95.3%	20.1%	5.3%	28,259
Gender/Sex													
Fem	45.3%	70.3%	25.0%	75.3%	30.0%	5.0%	69.8%	91.4%	21.5%	97.2%	27.4%	5.9%	1,208,617
Masc	44.7%	70.0%	25.3%	74.9%	30.2%	4.8%	69.6%	91.4%	21.8%	97.1%	27.5%	5.7%	1,050,206
Civil status													
Single	45.1%	70.2%	25.1%	74.9%	29.8%	4.7%	70.1%	91.8%	21.7%	97.3%	27.2%	5.5%	821,536
Married or cohabitation	45.0%	69.7%	24.8%	75.1%	30.1%	5.4%	69.6%	90.8%	21.1%	97.0%	27.4%	6.3%	896,958
Divorced or separated	49.8%	73.4%	23.6%	77.8%	28.0%	4.4%	72.3%	92.4%	20.0%	97.7%	25.3%	5.3%	163,980
Widow	55.1%	2.3%	-52.9%	79.3%	24.2%	77.1%	76.8%	93.5%	16.7%	97.8%	21.0%	4.3%	95,611
N.A.	37.2%	67.5%	30.3%	72.2%	35.0%	4.7%	63.8%	90.9%	27.1%	96.9%	33.0%	6.0%	254,492
N.D.	53.6%	71.4%	17.8%	76.4%	22.8%	5.1%	75.5%	90.1%	14.6%	95.0%	19.5%	4.9%	26,246
Age													
0-4	36.8%	67.4%	30.5%	72.1%	35.3%	4.7%	63.5%	90.8%	27.3%	96.9%	33.4%	6.1%	121,140
0-14	37.5%	67.6%	30.1%	72.2%	34.7%	4.6%	64.1%	91.1%	26.9%	96.8%	32.7%	5.8%	400,527
5-14	37.8%	67.7%	29.9%	72.3%	34.5%	4.6%	64.4%	91.2%	26.8%	96.8%	32.4%	5.6%	279,387
15-24	40.7%	68.6%	27.9%	73.4%	32.7%	4.8%	66.7%	91.2%	24.6%	97.0%	30.3%	5.7%	363,311
15-59	44.3%	69.6%	25.3%	114.4%	70.1%	44.8%	69.3%	91.1%	21.7%	97.1%	27.8%	6.1%	1,482,069
15-64	44.9%	69.9%	25.0%	75.0%	30.1%	5.1%	69.7%	91.1%	21.5%	97.1%	27.5%	6.0%	1,595,016
60+	55.8%	75.2%	19.4%	79.6%	23.9%	4.5%	77.1%	92.9%	15.7%	97.6%	20.5%	4.8%	376,227
65+	57.2%	75.8%	18.6%	80.1%	22.9%	4.3%	78.4%	93.2%	14.8%	97.8%	19.4%	4.6%	263,280
80+	62.6%	78.9%	16.3%	82.5%	20.0%	3.6%	81.2%	94.3%	13.1%	98.3%	17.0%	3.9%	64,100

Italics are used to show the difference/variation between figures on columns compared (located to the left).

Table 3: Predicted accessibility to the haemodialysis service with the shortest travel times (relative figures).

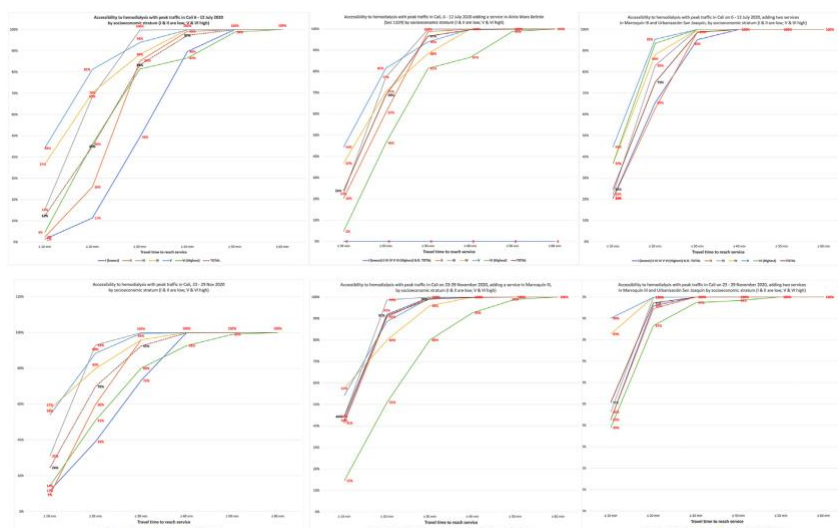


Fig. 9: Traffic variations and their effect (July vs November 2020) 6–12 July vs 23–29 November 2020.

of a holistic approach.^{2,4,5,30,31,66} These identified limitations impede the practical application of research findings, hindering their utility in supporting effective governance, monitoring, and fostering public engagement and a shared narrative to achieve equitable accessibility to health services.^{5,30,66–71}

Our focus lies in urban and metropolitan areas facing challenges with traffic congestion. Our methodology introduces a practical framework for local advocates, governments, and service providers to enhance and monitor health equity and accessibility.^{4,72,73} Measurements are updatable for monitoring and can be extended to various health services, transportation modes, or locations. Furthermore, the approach is adaptable for refinement, development, and integration with other data. Notably, being straightforward and intuitive to residents of congested cities, travel times exhibit a stronger association with costs compared to distance measurements.^{74–76}

In our preparatory phase, we surveyed studies that presented viewpoints from specific sectors such as mobility, health, or data sciences. However, we observed a gap in the literature where studies needed to establish connections between diverse stakeholders and relevant sectors, necessitating the role of evidence intermediaries or cultural brokers. While these studies often presented rich technical details and employed sophisticated methods, they generally needed the perspectives and

contextual information essential for meaningful discussions with diverse stakeholders or for facilitating policy implementation.^{5,30,66,73,77–79} Dynamic geographical accessibility assessments are gaining traction⁸⁰; however, our key informants expressed unfamiliarity with them, indicating that this remains a niche topic yet to be widely adopted in public policy and intersectoral actions.^{4,30,81,82}

Key informants from the government, patient representatives, service providers, urban observatories, and civic leaders contributed to the design of the AMORE web-based platform. Prototypes were developed in the second semester of 2020, aligning with principles of knowledge translation, social appropriation, and participatory planning.^{5,30,82–85}

DSTAM between the origin and destination TAZs allowed for accurate, granular and accessible assessments. Haemodialysis services are concentrated in areas distant from most of the population. Even during the early morning (5 AM) or late evening (11 PM) on weekdays, almost one-fifth of the population is beyond the 20-min travel threshold, including some of the poorest people and those living in outlying areas (Fig. 7). Our findings reveal haemodialysis accessibility inequalities, exposing vulnerable residents in outlying areas to longer journeys.^{28,86} Traffic congestion disproportionately affected people in the city's peripheries, particularly among low-income housing residents, certain ethnic groups like Afro-descendants, and

individuals with lower education attainment.^{87–89} This study highlights an “inverse care law,” illustrating that vulnerable populations bear a disproportionate burden to access health services.^{63–65,90,91}

The most vulnerable populations are likely to require haemodialysis and face higher costs, even if national insurance covers the treatment.^{92,93} Despite holistic approaches to address violence and social injustice in Cali, socioeconomic segregation has been pervasive, with land use and health services planning perpetuating the concentration of haemodialysis services in affluent areas of the city (Fig. 1).^{51,94–97}

Patient stories show that getting to services is challenging and physically demanding for patients living in outlying city areas. One haemodialysis patient explained, “I spent 4 h in haemodialysis. Many other patients would spend hours commuting to and from haemodialysis, whether on their car or shared rides arranged by health providers. Long travel times added to treatment duration, taking most of the time patients and companions had for other activities.” (Personal communication, Felipe Piquero, November 2022).^{9,16} The situation is even worse and riskier for those relying on public transportation. The scenarios studied here considered transportation by car, commonly used and deemed convenient by those seeking haemodialysis services.^{9,14,87,90,98} However, future studies could explore other means of transportation, link services with insurance, and integrate prevalence and incidence data or appointment availability to provide more refined information. They could also establish accessibility to services by being aware of appointments available or expanding to cover the entire metropolitan area and other communities accessing these services.

Applying the city’s prevalence of haemodialysis (128 per 100,000 people) to July’s estimations shows that adding services in Alirio Mora Beltrán would put 700,472 people within the 20-min threshold of those services, with an estimated 897 requiring haemodialysis; the figure could be higher considering that ESRD is more prevalent in low-income communities (Tables 2 and 3).

Adding services in Parcelaciones del Pance would put an additional 122,665 people within the 20-min threshold, which could result in an estimated 157 requiring haemodialysis. The two services would bring a population of 823,137 within the 20-min threshold, and about 1054 require haemodialysis (Tables 2 and 3).

While these estimations are simplistic and a proper one would have more nuances, they give an insight into the opportunities and possibilities of refining these test cases to guide decision-making.

The strategic location of new services will especially benefit populations in outlying areas and vulnerable groups such as low-income households, some ethnic groups, and people whose education attainment isn’t high. It will also likely ease the demand, reduce the workload, and minimise the need for night schedules for existing services.

We found no DSTAM for haemodialysis services published before the commencement of our project in the first half of 2020 that considered traffic congestion levels.²⁹ Despite calls for such studies, few assessments cover other treatments, and recently, these studies are emerging.^{2,23,27,69,99} None of the studies we identified provided a pathway to facilitate integration with urban and territorial planning or stakeholder engagement. A 2022 systematic review on geographic accessibility to radiotherapy found ten studies assessing travel time, and none considered traffic congestion gradients.¹⁰⁰ In the field of obstetrics, a survey conducted in 2023 highlighted two studies/dashboards that assessed the geographical accessibility of services in low or middle-income countries, including our project.¹⁰¹ Recognizing the proposal as innovative and receiving positive feedback from key informants who deemed it worthwhile, we tested the approach. The intention is to explore its potential for replication in other cities experiencing traffic congestion in Colombia (using the same data sources), Latin America, and various regions globally.^{3,53,80}

An immediate application of this data could be prioritising transportation or subsidising travel costs for people with longer travel times and vulnerable populations; data could be used to determine subsidy rates and to advance and monitor strategic objectives established in territorial health plans.^{51,102}

Accessibility assessments revealed the problem and predictions point at solutions. The AMORE web-based platform used heuristic genetic algorithms to identify the 1 or 2 locations where new services would maximise urban accessibility. We compared peak traffic congestion accessibility for July and November. We predict that adding services to the proposed TAZ would greatly enhance urban accessibility and health equity to levels that resemble current low traffic congestion (Interactive with the AMORE web-based platform).^{54,55} This indicates that accessibility-related inequalities can be addressed through political and civic will and land use arrangements if new services, at or near the one or two TAZ where haemodialysis accessibility is maximised, can absorb the demand.

Despite accessibility figures varying substantially in our two measurements, the optimal locations for new haemodialysis services did not. Our assessments suggest adding haemodialysis services in the eastern Agua Blanca district that all patients can access. The location remained consistent whether the prediction was made for adding services in one or two TAZs at a time (Fig. 8).

Different stakeholders are likely to understand and peruse the reported data and graphs with the descriptive statistics of the populations able to reach the haemodialysis service with the shortest travel time within a time threshold (Tables 1–3). Results were also presented in choropleth maps (heatmaps) to link the data to the territory, and in charts illustrating cumulative

accessibility opportunities. These reports, multimedia, and the published web-based platform should be suitable for multistakeholder dialogues.³⁰

Distinct elements of this innovation include an integral approach to health services planning providing: (1) an equity perspective using disaggregated socio-demographic information; (2) baseline and predicted assessments of traffic congestion's impact on geographical accessibility, established using DSTAM (3) simple charts, statistics, and cartography that integrate the territory, the population, haemodialysis services, and travel times that can be used to monitor or inform multistakeholder dialogues and participatory decision making. (4) a path to act on improving health equity and social justice.^{2,3,28,30,103,104} (5) options to test assumptions in the interactive platform, and^{10,37} (6) graphics that could unite stakeholders and sectors around common goals, such as "painting the city green", placing services close to patients, and integrating health equity with urban and territorial planning.^{2,5,28,105}

While all people requiring haemodialysis should have a service within a short travel time, this alone does not guarantee accessibility. Currently, coverage depends on agreements with service providers, and transportation is only sometimes provided. It would be ideal in Cali that in addition to services being added in strategic locations, patients are allowed to access services in any of the TAZs hosting them, and these services need to absorb the demand.

We suggest data updates to assess the post-COVID-19 situation, new demographics, infrastructure, and mobility.

If planning authorities must decide, we recommend adding sufficient services to cope with demand, first in the most impactful recommended location, using the July estimates, which seem to reflect typical conditions in Cali. However, a better option is to update the assessments as the COVID-19 pandemic recedes and new population and services data is available. The recommendation to add service(s) accessible to all patients in eastern Cali, near the Alirio Mora Beltrán neighbourhood, might not change. Implementing that recommendation would probably double accessibility and reduce inequities.

Generalisability

Our findings show that data on accessibility to haemodialysis can be obtained and delivered in user-accessible formats developed with stakeholders' input; this can be done with other services for which georeferenced information is available. This can likely be achieved in other countries offering open disaggregated data of services and population data (e.g., census, service registries) and travel time big data, usually sold by private providers. This is likely the case for many cities facing significant traffic congestion in Latin America and

beyond. DSTAM might be less valuable in uncongested areas, such as most rural settings, where travel-time variations are slight.

The study involved a multistakeholder, multidisciplinary group that included local data scientists, authorities and academics.³⁴ It can likely be replicated with local stakeholder engagement and city resources. For services such as tertiary care emergencies accessible to the entire population in Colombia and other countries, findings can be easily generalised. More precise measurements will require added layers of information for services where access is restricted, as was the case of haemodialysis in Cali. Nevertheless, the bigger picture may remain valid, as services are needed in densely populated neglected areas.

There is room for refinement by adding layers such as the incidence of end-stage kidney disease and the availability of haemodialysis chairs. Or integrating data about provider agreements or insurance coverage distribution among populations. Still, the recommendation of our study to add services that all citizens can access in the recommended areas might hold. Repeating these studies regularly as infrastructure, traffic conditions, and population change should be part of integrating health with urban territorial planning and monitoring of health equity.^{30,106}

Our findings indicate that strategically adding new services can dramatically improve accessibility and synergically advance SDG 3, SDG 10, and SDG 11 in Cali.

Studies used to rely on samples, fixed estimates, or analyses that missed the effects of the substantial impact of traffic congestion on health equity and accessibility.^{23,65,107,108} We have now tested an approach that addresses these issues. We suggest new metrics based on travel times to monitor accessibility for specific indicators, such as coverage for essential health services (3.8.1, the percentage of the population with access to essential health services) in urban areas with traffic congestion.

It also highlights that these data could promote civil society participation in urban and health services planning (SDG indicator 11.3.2). Urban planners and decision-makers can make sound decisions about the placement for healthcare facilities and discuss patient's needs and concerns about the distribution of resources.^{68,109–111} Cali's Territorial Health Plan 2020–2023 placed equitable access to health services among its strategic objectives to fulfil legal and constitutional mandates, and we present an approach to measure the fulfilment of this objective. DSTAM and predictions could inform stakeholders in shaping the 2024–2027 Territorial Health Plan implementation and monitoring.³¹ DSTAM could be used to put health equity higher on the agenda of local governments in cities with traffic congestion and advance the New Urban Agenda.^{4,5,112,113}

Limitations of the study

Variations between assessments are likely influenced by changes in travel restrictions and stay-at-home orders during the COVID-19 pandemic. It is still unknown how this influenced Google Distance Matrix algorithms.^{60,114} Empirical and anecdotal reports suggest they remained accurate.⁹⁹

The AMORE Project quantifies the impact of traffic congestion on accessibility to haemodialysis services. It reveals the populations affected, stressing the impact of inaction over a problem that can be addressed. It does not explain the contextual issues that have perpetuated Cali's segregation of sociodemographic and ethnic groups or haemodialysis and other health services concentration along the north-south corridor (Calle 5, 1st and 6th Avenues, Fig. 1) where many of the city's best-known landmarks and higher education institutions are located.^{94,95,115}

While we can broadly estimate demand for new services based on the prevalence of end-stage kidney disease and haemodialysis services, a proper analysis of demand for specific populations and sectors is unavailable. The geographic, ethnic, and socioeconomic distribution of haemodialysis patients in Cali is unknown to the research team.⁴⁸

For predictions to be met, patients should be given access to the service and integral treatments within the shortest travel time. Our estimates do not account for health services fragmentation present in Colombia's health system.

Accessibility to services might depend on insurance affiliation, and despite the eleven haemodialysis units being concentrated in six TAZ, it might well be that service provision fragmentation (i.e., insurance restrictions) or quality issues drive patients to services further beyond those with the shortest travel times, making our findings optimistic.

This report does not include an economic analysis, but low-income families might rely on just one or two minimum wages. Frequent long trips can hurt these families by consuming most of the minimum wage in travel costs.^{116–118} Low-income families are likely to live with three or fewer minimum wages and can easily incur catastrophic health costs well above 15% of their family income.^{119,120} This study does not adjust the socioeconomic stratum for low-paid, live-in domestic workers in middle or high-income households.

The integral treatment of terminal renal failure includes other ambulatory support education for patients and carers, therapies, and training, such as exercise and physical rehabilitation or nutrition.^{20,121–123} This can be provided in the same setting as haemodialysis, but we did not assess this.

Travel time between TAZs follows diverse daily patterns and directions with commuting impacting TAZs differently. Traffic clusters were sorted in incremental order for each TAZ, and it was found that the sorting

switched the order of contiguous clusters in fifteen cases. This has a minimal impact as variations between adjacent clusters are small. Poor road conditions can add to travel times and are not evenly distributed throughout the city.¹²⁴ Infrastructure changes, for example, road enhancements and new traffic light corridors controlled by artificial intelligence, might justify reassessing travel times.

This study did not assess appointment availability in services, a refinement that could be developed for the AMORE Platform.

Future assessments could include predictions for adding services to existing infrastructure, such as public hospitals.^{5,125} We tested this for tertiary care emergency services but not for haemodialysis; no public hospitals are near the recommended locations.

This report focuses on data generation and does not measure whether stakeholders, including those contributing to the study, peruse the new data this study provides to inform the city's territorial plans, which the incumbent administration will develop in 2024. As DSTAM develops research will likely enrich knowledge about its use.^{1,27,30,31,34,53,69,78,79,81,83,84,88,99–101,105,118,120,125–127}

While our study raises awareness about the pervasive lack of services within a short journey of the most heavily populated areas, it does not delve into the causes behind urban segregation, migration, and other historical challenges behind the disconnect between health equity aspirations and the realities seen in the city's development. The study exposes the situation, a vision of what concerted data-driven action could achieve for Cali, and an approach that could be used for monitoring.

Contributors

These were the author's contributions per Contributor Roles Taxonomy (CRediT)¹²⁸: **Luis Gabriel Cuervo (LGC)**: conceptualisation, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resources, software, supervision, validation, visualisation, led the writing of the original draft, reviewed and edited the draft and is the corresponding author; **Carmen Juliana Villamizar (CJV)**: data curation, project administration, supervision, contributed to the original draft, reviewed and edited the draft; **Lyda Osorio (LO)**: conceptualisation, methodology, reviewed and edited the draft; **María Beatriz Ospina (MBO)**: reviewed and edited the draft; **Diana E. Cuervo (DECD)**: reviewed and edited the draft; **Daniel Cuervo (DC)**: conceptualisation, formal analysis, methodology, resources, software, validation, visualisation, reviewed and edited the draft; **María O. Bula (MB)**: investigation, reviewed and edited the draft; **Pablo Zapata (PZ)**: software, validation, visualisation, reviewed and edited the draft; **Nancy J. Owens (NJO)**: reviewed and edited the draft; **Janet Hatcher-Roberts (JHR)**: reviewed and edited the draft; **Edith Alejandra Martín (EAM)**: reviewed and edited the draft; **Felipe Piquero (FP)**: reviewed and edited the draft; **Luis Fernando Pinilla (LFP)**: conceptualisation, data curation, software; **Eliana Martínez-Herrera (EMH)**: investigation, supervision, visualisation, reviewed and edited the draft; **Ciro Jaramillo (CJ)**: conceptualisation, data curation, formal analysis, investigation, methodology, supervision, validation, reviewed and edited the draft. All authors approved the final draft for publication and agreed to be accountable for all aspects of this report. LGC, CJV, and CJM directly accessed and verified the data; all authors were given access to the web-based AMORE platform when reviewing the draft manuscript. DCA, LFP, LGC and PZ verified the AMORE Platform data validity.

Dedication: This manuscript is dedicated to the late Dr. Arnoldo Bromet Schumm, a pioneer of family medicine in Cali, Colombia. In October 2021, Dr. Bromet Schumm agreed to join the AMORE Project, offering his insights as a haemodialysis patient, a healthcare provider, and an organiser of health services. He died in January 2022.

Data sharing statement

The travel-time datasets used by the AMORE web-based platform are available from OpenScience [July DOI 10.17605/OSF.IO/XDA87 and November DOI 10.17605/OSF.IO/FMJ2X], and the AMORE Platform's interactive interface used for this report is publicly available from the project's websites. Open data sources used in this study are listed in the Study Design and the cited protocol. Readers can interact with changing parameters and testing assumptions. These references include links to the website, tutorials, databases, blogs, and presentations about the AMORE Project.^{54,55}

The draft submitted for publication was also approved by the following members of the AMORE Project Collaboration who agreed to be accountable for all aspects of this report: Freddy Enrique Agredo Lemos, Germán Ávila Rodríguez, Alberto Concha-Eastman, Oscar H. Franco, Christian Camilo García Altamirano, María Fernanda Merino Juárez, Gynna Millán, Jackeline Murillo-Hoyos, Gabriel D. Paredes-Zapata, Oscar Rojas R, and María Fernanda Tobar-Blandón. Additional details are provided as a supplemental file.

Editor note

The Lancet Group takes a neutral position with respect to territorial claims in published maps and institutional affiliations.

Declaration of interests

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Disclaimers: The depiction of boundaries on included maps does not imply the expression of any opinion on the part of publishers concerning the legal status of any country, territory, jurisdiction or area or its authorities. This map is provided without any warranty, either express or implied. The maps we present in this publication were generated using open-source mapping services. Specifically, for Fig. 1, we utilized the Google Maps™ mapping service, incorporating map data sourced from ©2024 Google LLC. Figs. 2–9 and Supplemental File 1 were obtained using ©2023 Microsoft Corporation's resources, including Microsoft Bing and Microsoft Power BI™. Additionally, map data from ©Mapbox (www.mapbox.com), ©OpenStreetMap (www.openstreetmap.org), contributions from the public through "Improve this map" (<https://labs.mapbox.com/contribute>), and ©2022 TomTom were incorporated. This report was produced using Microsoft 365 apps and Adobe™ Creative Cloud applications. This report is an independent endeavour and is not associated with, endorsed, sponsored, or authorised by Google LLC, Adobe Inc., or Microsoft Corporation. Google Maps is a trademark of Google LLC, and Microsoft 365 is a trademark of Microsoft Corporation. We have added bearing and accessibility opportunity figures to maps for clarity purpose.

To improve the readability and language of the text during the revision process, the authors employed ChatGPT-3.5 by Open AI and Grammarly Premium for Mac ©2024, followed by manual checks and revisions.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.lana.2024.100752>.

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1.1.1 *International Journal for Equity in Health – Accessibility to radiotherapy.*

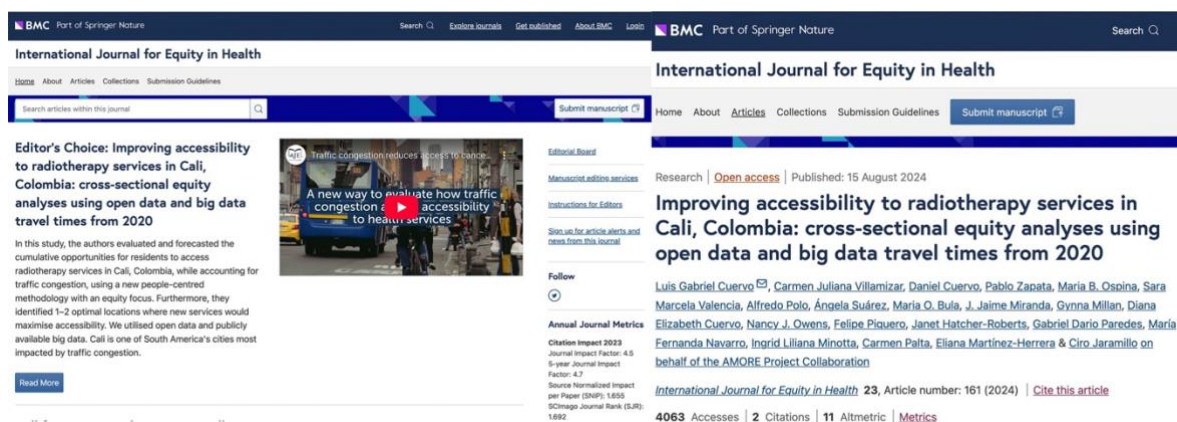
The third compendium publication was published in the *International Journal for Equity in Health*, with an **H-index of 93** and ranked Q1 for Health Policy and Public Health Environmental & Occupational Health by Scimago. The journal has an impact factor of 4.7. By the end of 2025, it had 5570 downloads and five citations. It remained one year as the journal *Editor's Choice*. The report describes the development and testing of the platform through a participatory approach that delivered dynamic accessibility assessments, forecasts of improvements from the addition of new healthcare services, and identified up to two facility locations that maximise urban accessibility in Cali, Colombia. The report included a videoabstract.

- Cuervo LG, Villamizar CJ, Cuervo D, Zapata P, Ospina MB, Valencia SM, Polo A, Suárez A, Bula MO, Miranda J, Millán G, Cuervo DE, Owens NJ, Piquero F, Hatcher-Roberts J, Paredes GD, Navarro MF, Minotta IL, Palta C, Martínez-Herrera E, Jaramillo C, on behalf of the AMORE Project Collaboration.

“Improving Accessibility to Radiotherapy Services in Cali, Colombia: Cross-sectional Equity Analyses Using Open Data and Big Data Travel Times from 2020.” *International Journal for Equity in Health*. 23, 161 (2024).

<https://doi.org/10.1186/s12939-024-02211-6> Video-abstract:

<https://youtu.be/8lC1JqywAwk>



Publication 1 – The Editor's Choice lasting one year.⁷⁹ (Open the file by clicking the image)

RESEARCH

Open Access



Improving accessibility to radiotherapy services in Cali, Colombia: cross-sectional equity analyses using open data and big data travel times from 2020

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Abstract

In this study, we evaluated and forecasted the cumulative opportunities for residents to access radiotherapy services in Cali, Colombia, while accounting for traffic congestion, using a new people-centred methodology with an equity focus. Furthermore, we identified 1–2 optimal locations where new services would maximise accessibility. We utilised open data and publicly available big data. Cali is one of South America's cities most impacted by traffic congestion.

Methodology: Using a people-centred approach, we tested a web-based digital platform developed through an iterative participatory design. The platform integrates open data, including the location of radiotherapy services, the disaggregated sociodemographic microdata for the population and places of residence, and big data for travel times from Google Distance Matrix API. We used genetic algorithms to identify optimal locations for new services. We predicted accessibility cumulative opportunities (ACO) for traffic ranging from peak congestion to free-flow conditions with hourly assessments for 6–12 July 2020 and 23–29 November 2020. The interactive digital platform is openly available.

Primary and secondary outcomes: We present descriptive statistics and population distribution heatmaps based on 20-min accessibility cumulative opportunities (ACO) isochrones for car journeys. There is no set national or international standard for these travel time thresholds. Most key informants found the 20-min threshold reasonable. These isochrones connect the population-weighted centroid of the traffic analysis zone at the place of residence to the corresponding zone of the radiotherapy service with the shortest travel time under varying traffic conditions ranging

*Eliana Martínez-Herrera and Ciro Jaramillo are senior authors.

https://padlet.com/Proyecto_AMORE_Project/Collaborators. AMORE stands for 'Análisis espacial con Macrodatos para Orientar Resultados en Equidad', which translates to 'Spatial Analysis with Big Data to Guide Equity Outcomes' in English.

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from free-flow to peak-traffic congestion levels. Additionally, we conducted a time-series bivariate analysis to assess geographical accessibility based on economic stratum. We identify 1–2 optimal locations where new services would maximize the 20-min ACO during peak-traffic congestion.

Results: Traffic congestion significantly diminished accessibility to radiotherapy services, particularly affecting vulnerable populations. For instance, urban 20-min ACO by car dropped from 91% of Cali's urban population within a 20-min journey to the service during free-flow traffic to 31% during peak traffic for the week of 6–12 July 2020. Percentages represent the population within a 20-min journey by car from their residence to a radiotherapy service. Specific ethnic groups, individuals with lower educational attainment, and residents on the outskirts of Cali experienced disproportionate effects, with accessibility decreasing to 11% during peak traffic compared to 81% during free-flow traffic for low-income households. We predict that strategically adding sufficient services in 1–2 locations in eastern Cali would notably enhance accessibility and reduce inequities. The recommended locations for new services remained consistent in both of our measurements.

These findings underscore the significance of prioritising equity and comprehensive care in healthcare accessibility. They also offer a practical approach to optimising service locations to mitigate disparities. Expanding this approach to encompass other transportation modes, services, and cities, or updating measurements, is feasible and affordable. The new approach and data are particularly relevant for planning authorities and urban development actors.

Español

En este estudio, evaluamos y pronosticamos las oportunidades acumulativas para que los residentes accedan a los servicios de radioterapia en Cali, Colombia, teniendo en cuenta la congestión del tráfico, utilizando una nueva metodología centrada en las personas con un enfoque de equidad. Además, identificamos 1–2 ubicaciones óptimas donde los nuevos servicios maximizarían la accesibilidad. Utilizamos datos abiertos y macrodatos disponibles públicamente. Cali está entre las ciudades Sudamericanas más afectadas por la congestión del tráfico.

Metodología: Usando un enfoque centrado en las personas, probamos una plataforma digital basada en la web desarrollada a través de un diseño participativo iterativo. La plataforma integra datos abiertos, incluyendo la ubicación de los servicios de radioterapia, los microdatos sociodemográficos desagregados de la población y los lugares de residencia, y los macrodatos de tiempos de viaje de la API de Google Distance Matrix. Usamos algoritmos genéticos para identificar ubicaciones óptimas para nuevos servicios. Pronosticamos oportunidades acumulativas de accesibilidad (ACO, por sus siglas en inglés) para el tráfico que va desde la congestión máxima hasta condiciones de flujo libre, con evaluaciones horarias hechas del 6 al 12 de julio de 2020 y del 23 al 29 de noviembre de 2020. La plataforma digital interactiva está públicamente disponible.

Resultados Primarios y Secundarios: Presentamos estadísticas descriptivas y mapas de calor de la distribución de la población basados en isócronas de ACO de 20 minutos para viajes en coche. No existe un estándar nacional o internacional establecido para estos umbrales de tiempo de viaje. La mayoría de los informantes clave encontraron razonable el umbral de 20 minutos. Estas isócronas conectan el centroide poblacional ponderado de la zona de análisis de tráfico del lugar de residencia con la zona correspondiente del servicio de radioterapia con menor tiempo de viaje bajo condiciones variables de tráfico, que van desde el flujo libre hasta niveles de congestión de tráfico máximo. Además, realizamos un análisis bivariado de series temporales para evaluar la accesibilidad geográfica basada en el estrato económico. Identificamos 1–2 ubicaciones óptimas donde los nuevos servicios maximizarían el ACO de 20 minutos durante la congestión máxima del tráfico.

Resultados: La congestión del tráfico redujo significativamente la accesibilidad a los servicios de radioterapia, afectando particularmente a las poblaciones vulnerables. Por ejemplo, el ACO urbano de 20 minutos en coche se redujo del 91% de la población urbana de Cali para viajes de hasta 20 minutos al servicio con flujo libre de tráfico, al 31% cuando hay congestión pico de tráfico durante la semana del 6 al 12 de julio de 2020. Los porcentajes representan la población con viajes de hasta 20 minutos en coche desde la residencia hasta el servicio de radioterapia. Grupos étnicos específicos, individuos con menor nivel educativo y residentes en las afueras de Cali experimentaron efectos desproporcionados, con la accesibilidad disminuyendo al 11% durante el tráfico máximo en comparación

con el 81% durante el tráfico de flujo libre para hogares de bajos ingresos. Predecimos que agregar estratégicamente suficientes servicios en 1-2 ubicaciones en el este de Cali mejoraría notablemente la accesibilidad y reduciría las inequidades. Las ubicaciones recomendadas para los nuevos servicios semantuvieron consistentes en nuestras dos mediciones.

Estos hallazgos subrayan la importancia de priorizar la equidad y la atención integral en la accesibilidad a la atención médica. También ofrecen un enfoque práctico para optimizar las ubicaciones de los servicios para mitigar las disparidades. Es factible y accesible expandir este enfoque para abarcar otros modos de transporte, servicios y ciudades, o actualizar las mediciones. El nuevo enfoque y los datos son particularmente relevantes para las autoridades de planificación y los actores del desarrollo urbano.

Português

Neste estudo, avaliamos e previmos as oportunidades cumulativas para os residentes acessarem serviços de radioterapia em Cali, Colômbia, levando em consideração o congestionamento do tráfego, utilizando uma nova metodologia centrada nas pessoas com um foco na equidade. Além disso, identificamos 1-2 locais ideais onde os novos serviços poderiam maximizar a acessibilidade. Utilizamos dados abertos e big data disponíveis publicamente. Cali está entre as cidades sul-americanas mais afetadas pela congestionamento do tráfego.

Metodologia: Usando uma abordagem centrada em pessoas, testamos uma plataforma digital baseada na web que foi desenvolvida através de um design participativo iterativo. A plataforma integra dados abertos, incluindo a localização dos serviços de radioterapia, microdados sociodemográficos desagregados por população e locais de residência, e big data da API Google Distance Matrix para os tempos de viagem. Utilizamos algoritmos genéticos para identificar locais ideais para novos serviços. Previmos oportunidades cumulativas de acessibilidade (ACO, por suas siglas em inglês) para o tráfego que varia desde o congestionamento máximo até condições de fluxo livre, com avaliações horárias de 6 a 12 de julho de 2020 e de 23 a 29 de novembro de 2020. A plataforma digital interativa está disponível publicamente.

Resultados Primários e Secundários: Apresentamos estatísticas descritivas e mapas de calor da distribuição populacional baseados em isócronas de ACO de 20 minutos para viagens de carro. Não existe um padrão nacional ou internacional estabelecido para esses limites de tempo de viagem. A maioria dos entrevistados-chave considerou razoável o limite de 20 minutos. Essas isócronas conectam o centroide ponderado pela população da zona de análise de tráfego no local de residência e sua zona correspondente do serviço de radioterapia com o menor tempo de viagem sob condições variáveis de tráfego (que vão desde fluxo livre até níveis máximos de congestionamento do tráfego). Além disso, realizamos uma análise bivariada de séries temporais para avaliar a acessibilidade geográfica baseada na estratificação econômica. Identificamos 1-2 locais ideais onde os novos serviços maximizariam a ACO de 20 minutos durante o pico de congestionamento do tráfego.

Resultados: O congestionamento do tráfego reduziu significativamente a acessibilidade aos serviços de radioterapia, afetando particularmente as populações vulneráveis. Por exemplo, a ACO urbana de 20 minutos de carro foi reduzida de 91% durante um fluxo livre de tráfego, para 31% durante picos de congestionamento de tráfego entre a semana de 6 a 12 de julho de 2020. As porcentagens representam a população com viagens de até 20 minutos de carro de sua residência até o serviço de radioterapia. Grupos étnicos específicos, indivíduos com menor nível educacional e residentes nos arredores de Cali experimentaram resultados desproporcionais, com a acessibilidade diminuindo para 11% durante o tráfego com congestionamento máximo em comparação com 81% durante o fluxo livre de tráfego para domicílios de baixa renda. Previmos que adicionar estrategicamente serviços suficientes em 1-2 locais no leste de Cali melhoraria significativamente a acessibilidade e reduziria as desigualdades. Os locais recomendados para os novos serviços permaneceram consistentes em ambas medições. Esses resultados ressaltam a importância de priorizar a equidade e o atendimento integral na acessibilidade aos cuidados de saúde. Eles também oferecem uma abordagem prática para otimizar os locais dos serviços a fim de minimizar as desigualdades. A expansão dessa abordagem para abranger outros modos de transporte, serviços e cidades, ou a atualização das medições, é viável e

acessível. A nova abordagem e os dados são particularmente relevantes para as autoridades de planejamento e os agentes do desenvolvimento urbano.

Français

Dans cette étude, nous avons évalué et prévu les opportunités cumulées pour les résidents d'accéder aux services de radiothérapie à Cali, en Colombie, tout en tenant compte de la congestion du trafic en utilisant une nouvelle méthodologie centrée sur les personnes avec axée sur l'équité. De plus, nous avons identifié 1 à 2 emplacements optimaux où de nouveaux services maximiseraient l'accessibilité. Nous avons utilisé des données ouvertes et des macrodonnées tenues à disposition du public. Cali est l'une des villes d'Amérique du Sud les plus touchées par la congestion du trafic.

Méthodologie: En utilisant une approche centrée sur les personnes, nous avons testé une plateforme numérique basée sur le web développée à travers une conception participative itérative. La plateforme intègre des données ouvertes, y compris la localisation des services de radiothérapie, les microdonnées sociodémographiques désagrégées de la population et les lieux de résidence, ainsi que les mégadonnées des temps de trajet de l'API Google Distance Matrix. Nous avons utilisé des algorithmes génétiques pour identifier les emplacements optimaux pour de nouveaux services. Nous avons prévu les opportunités cumulatives d'accessibilité (ACO), désignant l'acronyme en anglais) pour le trafic allant de la congestion maximale aux conditions de flux libre, avec des évaluations horaires du 6 au 12 juillet 2020 et du 23 au 29 novembre 2020. La plateforme numérique interactive est disponible publiquement.

Résultats Primaires et Secondaires: Nous présentons des statistiques descriptives et des cartes thermiques de la distribution de la population basées sur des ACO de 20 minutes pour les trajets en voiture. Il n'existe pas de norme nationale ou internationale établie pour ces seuils de temps de trajet. La majorité des informateurs clés ont trouvé le seuil de 20 minutes raisonnable. Ces isochrones relient le centroïde pondéré par la population de la zone d'analyse du trafic au lieu de résidence à la zone correspondante du service de radiothérapie avec le temps de trajet le plus court sous des conditions de trafic variables allant du flux libre aux niveaux de congestion de trafic maximum. De plus, nous avons réalisé une analyse bivariable des séries chronologiques pour évaluer l'accessibilité géographique en fonction de la stratification économique. Nous avons identifié 1 à 2 emplacements optimaux où de nouveaux services maximiseraient l'ACO de 20 minutes pendant la congestion maximale du trafic.

Résultats: La congestion du trafic a considérablement réduit l'accessibilité aux services de radiothérapie, affectant particulièrement les populations vulnérables. Par exemple, l'ACO urbain de 20 minutes en voiture est passé de 91 % de la population urbaine de Cali pour des trajets de jusqu'à 20 minutes vers le service avec un flux de trafic libre à 31 % lors des pics de congestion de trafic pendant la semaine du 6 au 12 juillet 2020. Les pourcentages représentent la population avec des trajets de jusqu'à 20 minutes en voiture depuis la résidence jusqu'au service de radiothérapie. Des groupes ethniques spécifiques, des individus ayant un niveau d'éducation inférieur et des résidents des périphéries de Cali ont subi des effets disproportionnés, avec une accessibilité diminuant à 11 % pendant le trafic maximal par rapport à 81 % pendant le flux de trafic libre pour les ménages à faible revenu. Ajouter suffisamment de services à 1-2 emplacements stratégiques dans l'est de Cali a le potentiel d'améliorer considérablement l'accessibilité et réduirait les inégalités. Les emplacements recommandés pour les nouveaux services sont restés cohérents dans nos deux mesures. Ces conclusions soulignent l'importance de prioriser l'équité et une prise en charge globale dans le cadre de l'accessibilité aux soins de santé. Elles offrent également une approche pratique pour optimiser les emplacements des services afin de réduire les disparités. Il est faisable et abordable d'étendre cette approche pour inclure d'autres modes de transport, services et villes, ou pour mettre à jour les mesures. La nouvelle approche et les données sont particulièrement pertinentes pour les autorités de planification et les acteurs du développement urbain.

What we know on this topic

The benefits of setting up new hospitals and health services in areas that are accessible and convenient to patients are well known, particularly for vulnerable populations. Moreover, people increasingly prefer to visit healthcare sites within a short trip where they spend their daily lives rather than embarking on long journeys or sitting in traffic. Direct and indirect costs associated with long journeys impact adherence, clinical outcomes, and patients' and their family's quality of life and economy. Having conveniently located health services contributes to spatial justice and health equity.

This report expands on our studies for haemodialysis and tertiary care emergency services. Those studies assessed the feasibility of generating dynamic geographical accessibility measurements by integrating open data and big data in participatory processes with stakeholders while incorporating an equity perspective. Our previous findings also identified eastern Cali as the priority area where new services would optimise accessibility. However, the recommended sectors varied as the distribution of haemodialysis and tertiary care emergency services differs from radiotherapy services.

What this study adds

This study introduces an innovative methodology and tool codesigned with stakeholders and data end users to be applied by the public and private sectors to strategically plan the establishment of new healthcare sites, focusing on urban accessibility to critical services such as radiotherapy. In addition to the participatory approach, the tool relies on relatable cartography and descriptive statistics to effectively communicate assessments and predictions regarding urban accessibility to radiotherapy services in Cali. It identifies optimal locations for new radiotherapy services, considering factors such as traffic congestion, and offers crucial data-driven insights for enhanced health services planning. This study tests a practical approach involving relevant stakeholders in response to numerous calls from leaders and intersectoral organisations advocating for participatory intersectoral actions to align the urban and health agendas by focusing on equity and social justice.

How might this study affect research, practice, or policy?

This study supports a fundamental shift in how accessibility measurements for health services are approached when traffic congestion is a factor. This approach equips advocates and stakeholders to participate in urban and health services planning with accurate and relatable data, fostering intersectoral and multistakeholder collaborations. The study also offers an interactive public platform for testing data and scenarios.

Governments, local authorities, and health/insurance companies benefit from incorporating these measurements into their health and urban planning policies. Civic organisations, government, and patient groups can explore how to monitor and link traffic congestion with equity and accessibility. This integration can improve overall accessibility, efficiency, and public participation. Moreover, the study can influence policies prioritising public health by underscoring the critical role of addressing traffic congestion in ensuring equitable access to health services. It sheds light on the impact of travel times as barriers to adherence and access to health services, particularly in conjunction with appointment opportunities, authorisations, and the fair allocation of subsidies.

Background

Traffic congestion reduces accessibility to health services and might affect population groups differently. However, measuring congestion has been elusive for practical reasons [1–3]. Most measurements have focused on average travel times or distances, which is problematic since fixed average estimates are misleading when traffic fluctuates and varies across sectors [3–7]. In these situations, residents often plan their movements based on travel times rather than distance due to the rarity of smooth, free-flow traffic that usually allows for predictable and economical transportation. In this article, we will refer to geographical accessibility measurements that consider temporospatial variations in traffic congestion as dynamic geographical accessibility measurements (DGAMs).

For example, a 2017 study using fixed estimates to measure accessibility to tertiary care emergency services in Cali, Colombia, yielded results like free-flow traffic in the first hours of weekdays, which a 2020 DGAM also captured. However, Cali is among the most traffic-congested cities in South America [8–10]. The DGAM showed that under usual traffic congestion conditions, 15-minute urban accessibility to tertiary care emergency services by car dropped from 84% to 38%, revealing a previously overlooked problem [11–15]. Reduced accessibility can adversely impact the overall quality of healthcare, life, and health outcomes.

DGAM studies are increasingly becoming available for health services [2, 6, 7, 16–19]. However, studies on accessibility to service provision are often done with minimal stakeholder involvement and disregard other knowledge translation recommendations [1, 20–27]. Furthermore, these studies employ complex methods and communicate findings to a specialised audience, which may not always be directly related to healthcare. While such assessments are very much needed in public health,

for example, to understand the interactions between patients and services, consider service agglomeration and spatial accessibility, or geographical distribution of service users and providers, [28, 29] reports are frequently of limited practical value in multistakeholder or intersectoral deliberations; they are usually cumbersome to update and rarely offer interactive options, rendering them ineffective for testing different scenarios, assumptions, monitoring, and planning [3, 13, 28, 30–34]. The AMORE Project and the OnTIME consortium are addressing some of these limitations, and this report for radiotherapy services adds to these. This report describes an innovative integrative approach that strategically engages diverse stakeholders involved in providing and receiving cancer treatment [5, 12, 18, 35–37]. While this report focuses on radiotherapy, the broader study tests a methodological approach applicable to diverse services within and beyond the health sector, providing an equity perspective and elements that differentiate it from existing approaches. For example, it points to where to place new services, going beyond describing service agglomeration to consider traffic congestion and urban sprawl, as well as the city's mobility network with the control measures that sometimes exacerbate inequities [36, 38].

A research project in Cali's informal settlements of the western peripheral Commune 18 produced qualitative data highlighting the problems people face when commuting to ambulatory cancer and dialysis services they require several times weekly [39–41]. These patients and their families can face financial hardship because of the high costs, direct and indirect (e.g., lost wages, missed opportunities) [42–49] (Supplementary Material 1).

Patients in Cali's slopes and other peripheral areas offer striking testimonies of the impact of their commute, frequently struggling to reach a paved road where a taxi can pick them up. Those in a wheelchair face the additional hurdle of finding a taxi that carries the chair. They sometimes struggle to find the money to pay for transportation, risking their well-being [39–41] (Supplementary Material 1).

Radiotherapy is an essential component of cancer care [50]. Radiotherapy capacities are strained and strategic efficient planning is needed to maximise efficiencies [51–53]. Comprehensive quality cancer treatments involving radiation therapy encompass additional interventions to improve physical, social, and mental well-being, providing support, education, and rehabilitation for patients and carers [54–57]. Radiotherapy is typically administered on an outpatient basis, requiring patients to visit the radiotherapy facility daily throughout the treatment course, which may span several weeks. This fact adds complexity to the analysis of accessibility to service provision.

Data and insights are needed to understand the factors contributing to poor spatial (geographical) accessibility

to radiotherapy services and to address health equity and social justice [2, 58–61]. Measuring the effects of traffic congestion on accessibility among populations enables data-driven approaches to address underlying issues. These include land-use policies or other factors contributing to market failure and service scarcity in underserved areas, including revenue, availability of specialists, or insecurity. Individual ability to pay is not directly linked to service payments in Colombia because health insurance schemes make most payments but need to cover transportation systematically [62]. A systematic review assessing the use of geographical information systems for radiotherapy planning found no studies providing an equity perspective that considered traffic congestion in low or middle-income countries, part of a multistakeholder coalition, or following a participatory people-centred approach [63]. We found no other studies co-designed with end users and stakeholders providing dynamic spatiotemporal accessibility measurements and predictions for health services [1]. Participation of beneficiaries and health services users in health services research promotes trust, effectiveness, community rights and several other benefits [37, 64].

Transportation subsidies are increasingly available in Colombia to treat high-cost diseases like cancer. However, these subsidies can perpetuate inequities because they need to account for factors that define out-of-pocket and indirect costs, such as travel time or distance. Furthermore, implementing these subsidies in 2020 was not systematic, leaving disadvantaged populations facing accessibility challenges [42, 65–68]. Poor geographical accessibility to cancer treatments diminishes the quality of care and is associated with poor clinical outcomes [56, 63, 69–73].

In this study, we aim to assess the impact of traffic congestion on the accessibility of radiotherapy services within urban Cali; explore the connections between sociodemographic factors influencing health equity, traffic congestion patterns, and the accessibility of healthcare services; and predict the enhanced accessibility of radiotherapy services by strategically introducing facilities in 1–2 key locations. This predictive model is designed to optimise service accessibility, cater to the healthcare needs of Cali's diverse population, and be accessible to diverse stakeholders [13, 29, 74].

Methods

This study outlines a new strategic people and equity-centred approach developed in 2020 to generate DGAMs for health services, combining a range of methods, novel processes, and ideas. The investigators comprise a multistakeholder international collaboration with governmental and non-governmental contributors taking a whole-of-system approach on health services

accessibility seeking to promote data-driven health services planning and health equity [75, 76]. The project examined tertiary care emergency services, for which time is critical, and two outpatient services that require frequent and prolonged attendance: haemodialysis and radiotherapy. This report focuses on the latter [38].

We developed the AMORE web-based platform to integrate open sources such as the adjusted national census microdata, matching it to a Traffic Analysis Zone (TAZ), and travel times between TAZ population-weighted centroids. This allowed us to obtain the dynamic spatial-temporal accessibility measurements (DSTAM) [12, 36, 38, 77]. The platform followed a participatory design approach with engagement from data scientists, researchers, collaborators and stakeholders throughout the design, implementation and reporting [13, 25, 38]. We held twenty-eight interviews and discussion groups with key informants, experts and stakeholders to get feedback and insights as the AMORE Platform was developed, leading to enhanced prototypes and presenting data in ways relatable to end users [13, 25, 38, 75]. Interviews with end users were expanded in 2023 as part of an innovation challenge and an assessment [13, 78]. We identified radiotherapy services in Cali using the Colombian National Health Services Registry (Supplementary Material 5). We obtained big data on travel times from Google Distance Matrix API for the weeks of July 6–12 and 23–29 November 2020 to perform situational analyses. On July 3, 2020, we downloaded predicted travel times for the week of 6–12 July 2021. For the week of 23–29 November 2020, we downloaded the expected times on 27 October 2020. None of these weeks had holidays, and they offered an opportunity to explore variations during the COVID-19 pandemic [12, 36, 38].

The AMORE web-based platform displays accessibility cumulative opportunities (ACO), a contour measure also known as isochronic indices, a metric for the number or proportion of opportunities of reaching a destination (i.e., radiotherapy service) within a specified travel time (i.e., 20 minutes by car) [9, 79]. It measured travel times from the population-weighted centroid of each residential TAZ to the centroid of the TAZ with the shortest travel time [38]. We used advanced heuristic genetic algorithms to predict the 1–2 locations where new services would maximise the accessibility across Cali. Those algorithms factored in disaggregated accessibility data by the socio-demographic population characteristics [36].

The 20-minute threshold was arbitrary and found reasonable by focus groups discussing commuting times for radiotherapy or haemodialysis. There is no set national or international standard for these travel time thresholds [38]. This was complemented by grading accessibility by socioeconomic stratum of housing at 10-minute intervals

to provide deeper perspectives into social justice and health equity [12, 36, 38, 61].

Study population and setting

Cali, a tropical city nested in a valley, lies between the western Andean mountains and the west bank of the Cauca River. Some of its neighbourhoods cover the western Andean slopes, including those along the road leading to the Pacific in northwest Cali on its westernmost border. Cali is the only major Colombian city with access to the Pacific coast (Fig. 1). This study focused on the urban population of Cali, as estimated for 2020 after updating the recorded 2018 national census microdata, as described in the research protocol.

Cali consisted of 22 communes in 2020 and began transitioning to becoming a Special District with six localities in 2023 [81–85]. This change might raise the interest of local advocates in accessibility assessments among constituencies concerned about the availability and quality of health services in their communities, as services will likely be concentrated in a few administrative districts.

Radiotherapy services

In 2020, Cali registered five radiotherapy facilities in the Colombian Special Registry of Health Services Providers (REPS in Spanish) [86]. Radiotherapy services are located in four TAZ along the north-south corridor on the lower part of the western Andean slopes and foothills, which are well-off areas of the city; two services at Imbanaco Medical Center are in the same TAZ. Four services are on the city's west and one, Fundación Valle de Lili, in the south, all in well-off areas (Fig. 1).

However, some high-income residents live in villas and mansions in southern Cali, and high-income housing hosts 9% of the population, including low-income resident homeworkers; almost half of the population lives in low-income areas, mainly in the city's east and peripheral areas (Fig. 2) [80]. According to REPS, these radiotherapy facilities have extended hours from Monday to Saturday, providing crucial healthcare services.

Radiotherapy services are a sophisticated, expensive technology delivered by highly trained teams, with specialised radiotherapy modalities (e.g., 3D Conformal Radiotherapy, Intensity-Modulated Radiation Therapy, Image Guided Radiation Therapy, Stereotactic Body Radiation Therapy, Proton Therapy) beyond conventional radiotherapy (i.e., 2D Conformal Radiotherapy). There is an opportunity to look at the accessibility issues seeking to ensure a sound distribution of treatment modalities for existing service clusters and new centres to offer most common treatment options within



Fig. 1 Location of Cali's radiotherapy services in 2020, with compass rose, mountain range, and road indications for clarity [80]

reasonable travel times from where most of the population resides [57, 87, 88].

Study design

This cross-sectional study used the AMORE web-based platform to integrate big data of travel times with georeferenced microdata from the adjusted 2018 national census, TAZs, and the geographic locations of radiotherapy services [12, 38, 89, 90]. The data sources integrated into the platform included the 2018 National Census Data for Cali, obtained from the public official databases of the Colombian National Department of Statistics (DANE in Spanish); [91, 92] administrative divisions

of Cali obtained from the Colombian IDESC Geoportal, Traffic Analysis Zones (TAZs), and census block sectors [93, 94]; Google's Distance Matrix API; and information about the five radiation therapy services in Cali. The study's complete list of variables can be found in the protocol and previous reports [12, 36, 38].

Travel times varied substantially during the COVID-19 pandemic. It is unclear how this influenced Google Distance Matrix algorithms [95]. As previously reported, everything indicates that these estimations remained accurate [36]. Radiotherapy facility data was obtained using REPS service codes 711 (radiotherapy as complementary or diagnostic treatment)

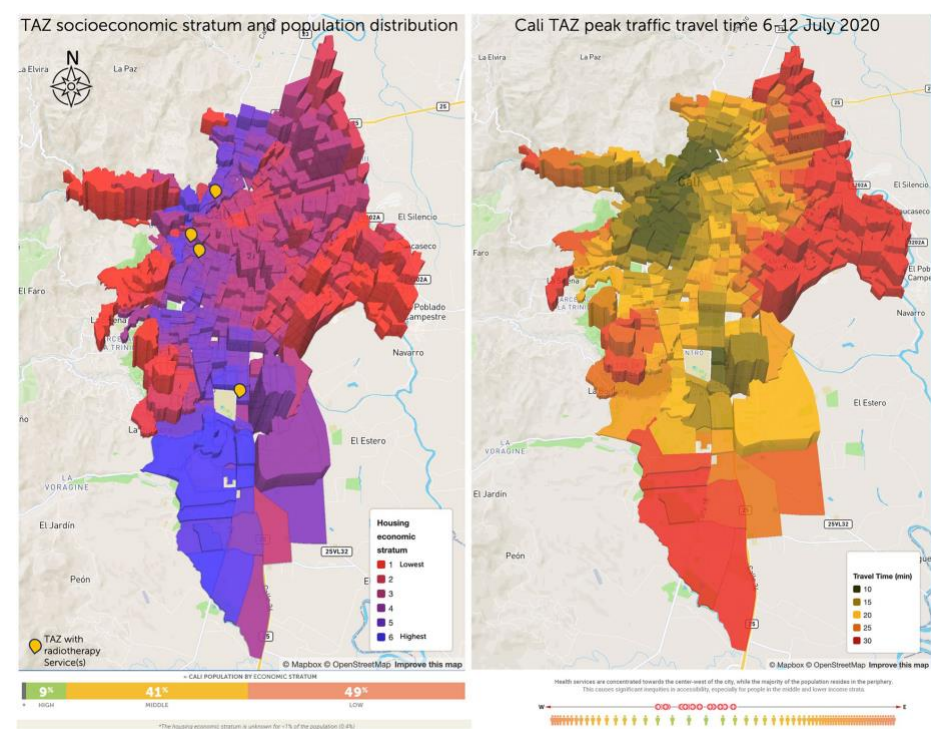


Fig. 2 Population distribution of Cali's 2020 TAZs by housing economic stratification and travel time

and 408 (outpatient radiotherapy). Centres were registered under both service codes in 2020 and remained unchanged as of 30 November 2023 (Supplementary Material 5) [80, 86]. We did not include providers offering only nuclear medicine (code 715).

Statistical analysis

Our report provides frequencies and bivariate analyses to represent cumulative opportunities as a measure of accessibility [79]. Critical variables for this report are travel time from the population weighed centroid of each residential TAZ to that of the TAZ hosting the radiotherapy service with the shortest journey time and the housing and sociodemographic characteristics of the population, as recorded in the Colombian national census microdata [38, 96]. The AMORE web-based platform displays population absolute and relative distribution (percentages) per travel time threshold measured for

each of the nine traffic congestion levels, ranging from free-flow to peak traffic congestion [12]. We use isochrones or choropleths to represent the shortest median journey time required to reach a radiotherapy service at each hour of the day throughout the week. Univariate and bivariate analyses are described in the protocol and reports [12, 36, 38].

Results / Outcomes

Participants

This study focused on the urban population of Cali registered in the 2018 census, adjusted to 2020 figures, with 2,258,823 residents [38]. Most of the population is mestizo or white (83.7 %, labelled in the census as “Others”) or Afro-descendants (326,492; 14.5%). Islanders (from the Department of San Andrés and Providencia) and Rrom people represent less than 1% of the population [97]. Residents are distributed in 507 TAZs, comprising 596,051

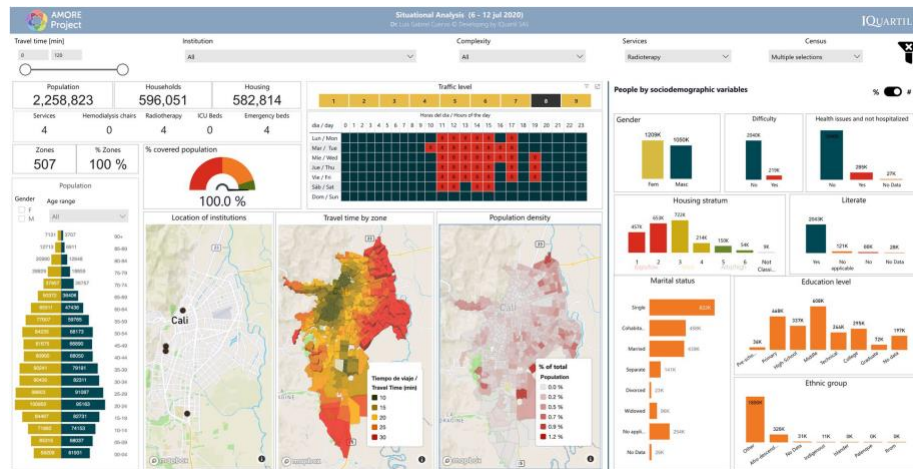


Fig. 3 AMORE web-based Platform demographics interface (absolute figures) [98]

households within 582,814 housing units. Figure 3 illustrates how the AMORE platform's interface displays the sociodemographic characteristics of the population, available from Tables 1 and 2, and previous reports describe the platform's interface in detail [12, 36, 38].

The socioeconomic distribution of dwellings for Cali shows that 1,109,549 residents (49% of the population) live in low-income housing. Most low-income housing is in the eastern and northeastern Cali and the western Andean slopes, including the areas along the road to the Pacific coast on its westerly limits. Most of the 935,699 middle-income Cali residents (about 41% of the population) live in 257,153 households in the central and south-east corridors of the city (Figs. 2 and 3) [12, 36].

Colombian national high-cost treatment monitoring services reported 527 new radiotherapy schemes (incident cases) in the five radiotherapy centres in Cali in 2020 (Cuenta de Alto Costo, Data request 5376, 29 May 2023. Supplementary Material 6). While most Cali residents, including those in vulnerable situations, live in densely populated outlying regions, radiotherapy services are in well-off areas with low population density (Fig. 2) [38].

Baseline situational analyses

Figure 3 shows the situational analysis interface for Cali's population in July 2020; Tables 1 and 2 present the peak traffic 20-min ACO and its distribution by housing income categorisation, and sociodemographic characteristics like ethnicity, gender, age, education level, and civil status per adjusted census [38, 98].

Figures 4 and 5 show the interface for July and November, respectively, with a travel-time threshold of 20 minutes and relative population data [98]. Figure 6 complements these data, showing the territorial distribution variations for the July and November assessments and the matching population by housing income groups. It reflects improvements from reduced traffic congestion in November, when accessibility doubled.

Effect of traffic variations (6–12 July vs 23–29 November 2020)

We found that, due to heavy traffic congestion, most people living in low-income housing and the city's periphery had lower geographic accessibility to radiotherapy services in November 2020 and July 2020 (Table 1, Figs. 4, 5, 6, 7, 8 and 9). Traffic congestion exacerbated inequities by disproportionately impacting the poorest populations in densely populated areas and the city's outskirts (Table 1, Fig. 6, Supplementary Material 3 and Fig. 7); travel times are an access barrier to radiotherapy. Traffic congestion significantly decreased in the November measurements following the reinstatement of COVID-19 pandemic measures, such as stay-at-home orders and license-plate-based driving restrictions. In contrast, such measures were absent in July, leading to lower accessibility, particularly for residents in low-income housing (11.2% in July compared to 42.8% in November) and middle-income housing (42.8% in July compared to 75% in November). The change was less dramatic for those in high-income housing, with

Table 1 Relative figures: situational analysis and predicted 20-minute ACO by car to radiotherapy in Cali in July and November 2020

20-min accessibility opportunity to radiotherapy services	Jul 2020 (%)	Add 1 Location	Variation vs baseline	Add 2 Locations	Variation vs baseline	Benefit of 2 vs 1 location	Nov 2020 (%)	Add 1 Location	Variation vs baseline	Add 2 Locations	Variation vs baseline	Benefit of 2 vs 1 location	Population
	30.8%	61.6%	30.8%	82.6%	51.8%	21.0%	60.4%	91.5%	31.1%	99.4%	39.0%	7.9%	
Socio-economic stratum													
Low	11.2%	47.6%	36.4%	80.5%	69.3%	32.9%	42.8%	88.7%	45.9%	99.6%	56.8%	10.8%	1,109,549
Middle	42.8%	73.7%	30.8%	84.1%	41.3%	10.4%	75.0%	95.3%	20.3%	100.0%	25.0%	4.7%	935,699
High	82.6%	83.0%	0.4%	87.3%	4.8%	4.4%	89.5%	89.9%	0.4%	96.3%	6.8%	6.4%	204,589
N.D.	30.3%	55.6%	25.3%	76.7%	46.4%	21.1%	58.5%	84.5%	26.1%	97.3%	38.8%	12.8%	8,986
Ethnicity													
Afrodescendent	15.2%	53.7%	38.5%	85.2%	70.0%	31.5%	42.8%	88.9%	46.1%	99.8%	57.1%	11.0%	325,865
Rrom (nomadic)	24.5%	53.9%	29.4%	74.5%	50.0%	20.6%	53.9%	89.2%	35.3%	95.1%	41.2%	5.9%	102
Indigenous	28.9%	53.0%	24.1%	70.9%	42.0%	17.9%	67.5%	94.9%	27.3%	98.9%	31.3%	4.0%	11,112
Islander/Raizal	40.3%	64.1%	23.8%	80.4%	40.1%	16.2%	64.7%	91.1%	26.4%	98.2%	33.5%	7.1%	382
Other (Caucasian, Mestizo)	33.4%	63.0%	29.6%	82.2%	48.8%	19.2%	63.3%	92.0%	28.7%	99.4%	36.1%	7.4%	1,890,491
Palenque	11.0%	19.2%	8.2%	78.8%	67.8%	59.6%	78.8%	87.8%	9.0%	100.0%	21.2%	12.2%	245
N.D.	41.3%	63.6%	22.3%	82.9%	41.6%	19.3%	68.4%	90.6%	22.2%	97.9%	29.5%	7.3%	30,626
Educational level													
Graduate degree	67.4%	77.3%	9.9%	84.5%	17.0%	7.2%	84.1%	91.9%	7.8%	97.8%	13.7%	5.9%	72,441
Bachelor Degree	53.1%	72.6%	19.6%	84.2%	31.2%	11.6%	76.7%	92.7%	16.0%	99.0%	22.4%	6.4%	295,319
Technical	32.8%	64.5%	31.8%	83.9%	51.1%	19.4%	63.4%	92.2%	28.8%	99.7%	36.3%	7.5%	244,160
Middle	25.7%	60.0%	34.3%	82.7%	57.0%	22.7%	56.3%	91.4%	35.1%	99.6%	43.3%	8.2%	608,429
High School	24.3%	58.1%	33.8%	82.2%	57.9%	24.0%	55.7%	91.2%	35.5%	99.5%	43.8%	8.4%	337,065
Primary	23.3%	57.2%	33.9%	81.2%	57.8%	23.9%	55.5%	91.5%	36.0%	99.5%	44.1%	8.0%	468,206
Pre-school	25.1%	56.5%	31.4%	81.6%	56.5%	25.1%	55.8%	89.5%	33.7%	99.3%	43.5%	9.8%	36,294
No data	27.5%	58.0%	30.5%	81.6%	54.1%	23.6%	57.1%	90.3%	33.2%	99.3%	42.2%	8.9%	196,909
Literacy													
Literate	31.4%	62.1%	30.8%	82.7%	51.4%	20.6%	60.9%	91.7%	30.8%	99.4%	38.5%	7.8%	2,043,041
No literacy	21.1%	52.5%	31.4%	79.8%	58.7%	27.2%	52.7%	89.7%	37.0%	99.5%	46.8%	9.8%	66,383
N.A.	24.6%	57.0%	32.5%	81.7%	57.1%	24.6%	54.7%	90.1%	35.4%	99.5%	44.8%	9.4%	121,140
N.D.	41.6%	65.3%	23.7%	82.8%	41.2%	17.5%	67.9%	90.8%	22.9%	97.9%	30.1%	7.1%	28,259
Gender/Sex													
Fem	31.2%	61.8%	30.6%	82.7%	51.5%	20.9%	60.6%	91.5%	30.9%	99.4%	38.9%	7.9%	1,208,617
Masc	30.4%	61.4%	31.0%	82.5%	52.1%	21.1%	60.2%	91.5%	31.3%	99.4%	39.2%	7.9%	1,050,206
Civil status													
Single	30.7%	61.3%	30.7%	82.4%	51.7%	21.0%	60.6%	91.7%	31.0%	99.5%	38.8%	7.8%	821,536
Married or cohabitation	31.3%	61.9%	30.6%	82.6%	51.3%	20.7%	60.5%	91.4%	30.9%	99.4%	38.9%	7.9%	896,958
Divorced or separated	33.3%	64.9%	31.6%	84.2%	51.0%	19.3%	62.6%	92.6%	30.0%	99.6%	37.0%	7.1%	163,980
Widow	37.3%	66.8%	29.5%	84.8%	47.5%	17.9%	66.5%	93.2%	26.7%	99.6%	33.1%	6.4%	95,611
N.A.	24.6%	57.1%	32.6%	81.5%	56.9%	24.4%	54.9%	90.2%	35.3%	99.5%	44.5%	9.3%	254,492
N.D.	41.7%	64.8%	23.1%	82.7%	41.0%	17.8%	68.4%	90.9%	22.5%	97.8%	29.5%	6.9%	26,246
Age													
0-4	24.6%	57.0%	32.5%	81.7%	57.1%	24.6%	54.7%	90.1%	35.4%	99.5%	44.8%	9.4%	121,140
0-14	24.6%	57.3%	32.7%	81.5%	56.9%	24.2%	55.0%	90.2%	35.3%	99.4%	44.4%	9.2%	400,527
5-14	24.6%	57.4%	32.8%	81.4%	56.8%	24.0%	55.1%	90.3%	35.2%	99.4%	44.3%	9.1%	279,387
15-24	27.1%	59.0%	31.8%	81.7%	54.5%	22.7%	57.6%	91.1%	33.5%	99.4%	41.8%	8.3%	363,311
15-59	30.3%	61.3%	31.0%	82.4%	52.1%	21.1%	60.1%	91.5%	31.3%	99.4%	39.3%	8.0%	1,482,069
15-64	30.8%	61.6%	30.8%	82.5%	51.7%	20.9%	60.4%	91.5%	31.1%	99.4%	39.0%	7.9%	1,595,016
60+	39.6%	67.6%	28.0%	84.6%	45.0%	17.0%	67.4%	93.2%	25.7%	99.5%	32.0%	6.3%	376,227
65+	40.7%	68.4%	27.7%	84.8%	44.1%	16.4%	68.6%	93.6%	24.9%	99.5%	30.9%	5.9%	263,280
80+	44.4%	70.7%	26.2%	85.6%	41.2%	14.9%	73.1%	94.6%	21.5%	99.6%	26.5%	5.0%	64,100

accessibility rates of 82.6% in July compared to 89.5% in November (Table 1, Figs. 6 and 9).

In July, Afro-descendants and the smaller Palenque community experienced the lowest accessibility rates, with 15.2% and 11%, respectively. In contrast, Islander and 'Other' populations (including whites and mestizos) fared significantly better, with accessibility rates of 40% and 33.4%, respectively. An earlier report showed that the small Palenque population is concentrated in a few neighbourhoods [12]. Because most of this population lives near the 20-minute ACO threshold borders, accessibility improved greatly when traffic congestion eased in November, reaching an accessibility rate of 78.8%, followed by indigenous communities at 67.5% (Table 2).

Individuals with graduate and bachelor's degrees consistently experienced better accessibility and were less affected by reduced traffic congestion. Marital status also influenced accessibility, with married individuals or those in partnerships having lower accessibility in July (calculated to 31.3%, based on Table 2). However, as traffic congestion

eased in November, accessibility rates became more uniform across different marital statuses, ranging from 60.5% for couples to 66.5% for widowers (Tables 1 and 2).

We observed an age-related gradient in accessibility, with older populations enjoying better access. Interestingly, all age groups benefited similarly from the traffic congestion relief (Tables 1 and 2).

Effects of the addition of new radiotherapy providers

We analysed what peak-traffic accessibility would look like if new radiotherapy facilities were optimally located in 1–2 TAZs. Optimisation analyses for urban accessibility during peak traffic hours consistently pointed to adding new services in the eastern sector of *La Base* (Figs. 8 and 11). This finding was consistent for both measurement periods. Simulating the addition of this new service in July increased predicted urban accessibility from 30.8% to 61.6%. This addition expanded the 20-minute ACO to include 695,502 more inhabitants (Table 2).

Table 2 Population data: situational analysis and predicted 20-minute ACO by car to radiotherapy in Cali in July and November 2020

20-min accessibility opportunity to radiotherapy services	Jul 2020 (#)	Add 1 Location	Variation vs baseline	Add 2 Locations	Variation vs baseline	Benefit of 2 vs 1 location	Nov 2020 (#)	Add 1 Location	Variation vs baseline	Add 2 Locations	Variation vs baseline	Benefit of 2 vs 1 location
	696,327	1,391,829	695,502	1,865,381	1,169,054	473,552	1,364,832	2,067,450	702,618	2,245,876	881,044	178,426
Socio-economic stratum												
Low	123,977	527,803	403,826	892,794	768,817	364,991	474,595	984,401	509,806	1,104,619	630,024	120,218
Middle	400,720	689,313	288,593	786,990	386,270	97,677	701,804	891,483	189,679	935,418	233,614	43,935
High	168,909	169,720	811	178,706	9,797	8,986	183,180	183,971	791	197,097	13,917	13,126
N.D.	2,721	4,993	2,272	6,891	4,170	1,898	5,253	7,595	2,342	8,742	3,489	1,147
Ethnicity												
Afrodescendent	49,557	174,905	125,348	277,654	228,097	102,749	139,457	289,643	150,186	325,366	185,909	35,723
Rom (nomadic)	25	55	30	76	51	21	55	91	36	97	42	6
Indigenous	3,211	5,889	2,678	7,881	4,670	1,992	7,504	10,542	3,038	10,987	3,483	445
Islander/Raizal	154	245	91	307	153	62	247	348	101	375	128	27
Other (Caucasian, Mestizo)	630,694	1,191,204	560,510	1,553,869	923,175	362,665	1,196,437	1,738,850	542,413	1,878,821	682,384	139,971
Palenque	27	47	20	193	166	146	193	215	22	245	52	30
N.D.	12,659	19,484	6,825	25,401	12,742	5,917	20,939	27,761	6,822	29,985	9,046	2,224
Educational level												
Graduate degree	48,842	55,998	7,156	61,184	12,342	5,186	60,924	66,580	5,656	70,880	9,956	4,300
Bachelor Degree	156,669	214,438	57,769	248,721	92,052	34,283	226,424	273,619	47,195	292,496	66,072	18,877
Technical	80,075	157,600	77,525	204,846	124,771	47,246	154,822	225,088	70,266	243,462	88,640	18,374
Middle	156,269	365,144	208,875	503,350	347,081	138,206	342,481	556,196	213,715	606,040	263,559	49,844
High School	81,902	195,958	114,056	276,927	195,025	80,969	187,782	307,293	119,511	335,498	147,716	28,205
Primary	109,257	267,945	158,688	380,013	270,756	112,068	259,723	428,320	168,597	466,001	206,278	37,681
Pre-school	9,105	20,507	11,402	29,627	20,522	9,120	20,243	32,471	12,228	36,031	15,788	3,560
No data	54,208	114,239	60,031	160,713	106,505	46,474	112,433	177,883	65,450	195,468	83,035	17,585
Literacy												
Literate	640,804	1,269,424	628,620	1,690,092	1,049,288	420,668	1,244,436	1,873,051	628,615	2,031,606	787,170	158,555
No literacy	14,004	34,873	20,869	52,953	38,949	18,080	34,956	59,536	24,580	66,030	31,074	6,494
N.A.	29,752	69,073	39,321	98,927	69,175	29,854	66,264	109,202	42,938	120,567	54,303	11,365
N.D.	11,767	18,459	6,692	23,409	11,642	4,950	19,176	25,661	6,485	27,673	8,497	2,012
Gender/Sex												
Fem	377,043	747,029	369,986	999,369	622,326	252,340	732,264	1,106,265	374,001	1,201,820	469,556	95,555
Masc	319,284	644,800	325,516	866,012	546,728	221,212	632,568	961,185	328,617	1,044,056	411,488	82,871
Civil status												
Single	252,027	503,866	251,839	676,636	424,609	172,770	498,066	753,108	255,042	817,220	319,154	64,112
Married or cohabitation	280,616	555,268	274,652	740,502	459,886	185,234	542,786	820,054	277,268	891,311	348,525	71,257
Divorced or separated	54,547	106,410	51,863	138,132	83,585	31,722	102,647	151,780	49,133	163,370	60,723	11,590
Widow	35,666	63,904	28,238	81,064	45,398	17,160	63,585	89,100	25,515	95,199	31,614	6,099
N.A.	62,522	145,365	82,843	207,350	144,828	61,985	139,805	229,555	89,750	253,100	113,295	23,545
N.D.	10,949	17,016	6,067	21,697	10,748	4,681	17,943	23,853	5,910	25,676	7,733	1,823
Age												
0-4	29,752	69,073	39,321	98,927	69,175	29,854	66,264	109,202	42,938	120,567	54,303	11,365
0-14	98,478	229,461	130,983	326,457	227,979	96,996	220,183	361,459	141,276	398,148	177,965	36,689
5-14	68,726	160,388	91,662	227,530	158,804	67,142	153,919	252,257	98,338	277,581	123,662	25,324
15-24	98,577	214,216	115,639	296,676	198,099	82,460	209,280	330,960	121,680	361,028	151,748	30,068
15-59	449,040	908,079	459,039	1,220,688	771,648	312,609	890,955	1,355,432	464,477	1,473,500	582,545	118,068
15-64	490,654	982,231	491,577	1,315,601	824,947	333,370	963,917	1,459,675	495,758	1,585,770	621,853	126,095
60+	148,809	254,289	105,480	318,236	169,427	63,947	253,694	350,559	96,865	374,228	120,534	23,669
65+	107,195	180,137	72,942	223,323	116,128	43,186	180,732	246,316	65,584	261,958	81,226	15,642
80+	28,489	45,315	16,826	54,875	26,386	9,560	46,869	60,627	13,758	63,828	16,959	3,201

This improvement remained substantial in November, with accessibility rising from 60.4% to 91.5% and incorporating 702,618 more inhabitants into the 20-minute ACO, markedly raising accessibility rates for all income levels and nearly all marital statuses, education levels, and ethnic groups. These results indicate that adding radiotherapy services in eastern Cali, specifically in or near La Base, will likely address critical health equity concerns related to accessibility (Tables 1 and 2 and Fig. 9).

Adding services in two new locations would notably increase Cali's accessibility to radiotherapy services. While July and November predictions point to four different geographical areas, the recommended sectors are located nearby in the northeast and southeast (Fig. 9). July predictions showed that adding radiotherapy services in La Alianza in the northeast and Rodrigo Lara Bonilla in the southeast would increase peak-traffic ACO opportunities by 168%, reaching 82.6% of the population

(Fig. 12), with 1,169,054 inhabitants incorporated into the 20-minute peak-traffic ACO (compared to the baseline). Similarly, November predictions revealed that locating services at Los Parques de Barranquilla in the northeast would accommodate around 450,000 inhabitants, and at Los Comuneros III in the southeast, it would serve about 842,000 into the 20-minute peak-traffic ACO (Fig. 8).

The evidence, drawn from measurements in July and November, shows that introducing new radiotherapy services in recommended locations would improve accessibility, particularly in eastern Cali, and reduce inequities (Figs. 9, 10, 11 and 12). Moreover, the data also shows that it is better to add more sites. In July, the increase from adding two sites instead of one was 21.0%. In November, although lower by 7.9% (178,426), this increase still improves ACO for a large population (Supplementary Material 7 and 8).

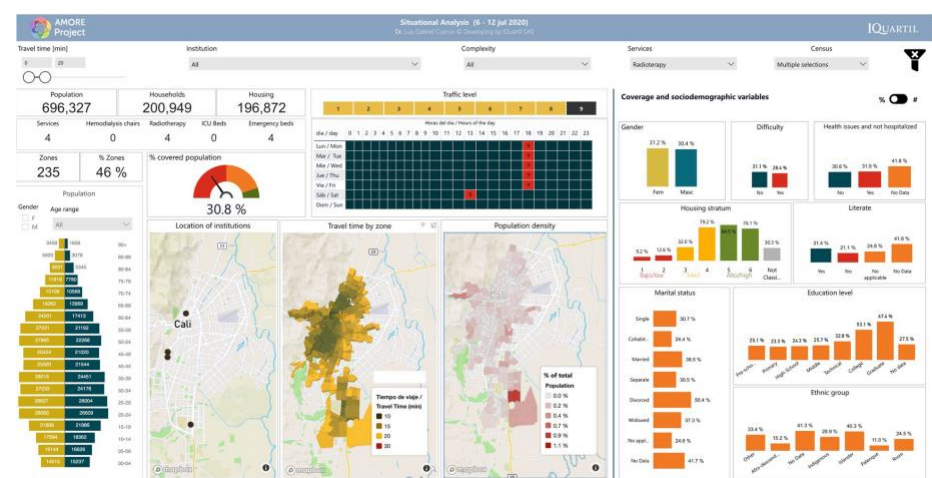


Fig. 4 Relative 20-min peak-traffic ACO by car to radiotherapy, 6–12 July 2020 [98]

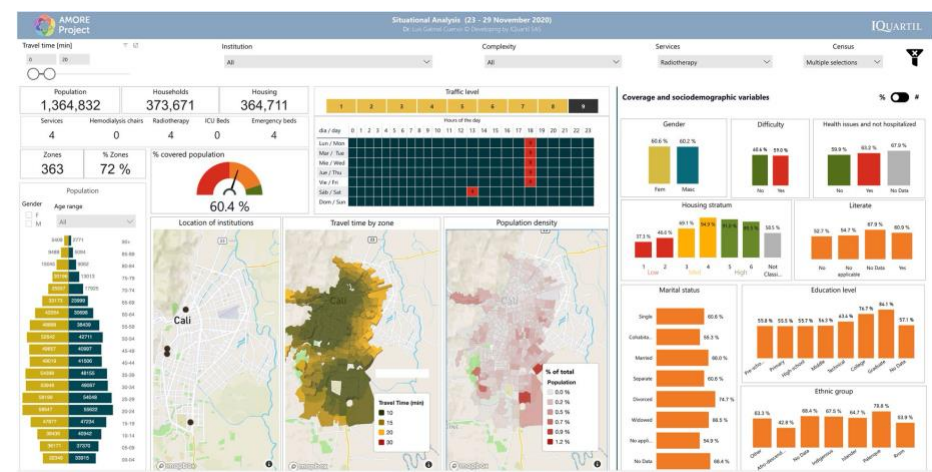


Fig. 5 Relative 20-min peak-traffic ACO by car to radiotherapy 23–29, November 2020 [98]

Other analyses

Comparing July and November 2020

We measured the gradients by which traffic fluctuations from free flow to peak traffic affect populations per housing economic stratum (Fig. 7). We found that the negative impact of traffic congestion is more remarkable for the

lower-income stratum groups. We found a small high-income population living in villas in the city's southern outskirts that remains beyond the 20-minute ACO.

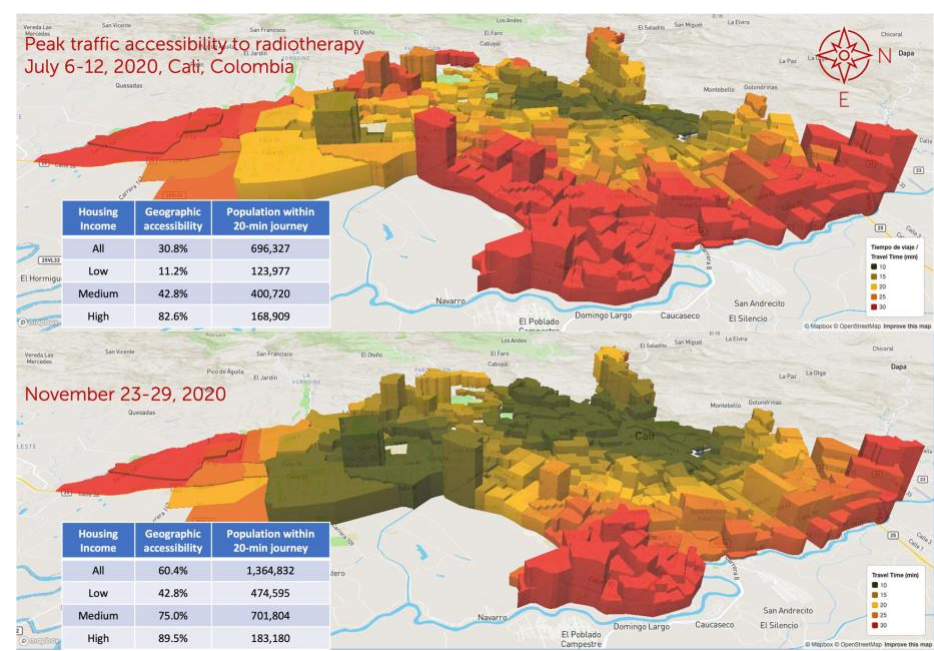


Fig. 6 Assessed accessibility in July and November 2020 by economic stratum and location, with TAZ height representing population

Discussion

The city’s layout and demography have changed since the city was concentrated around the corridor where services are located, and our findings offer a justification for updating land-use and health services plans. The new data provide insights for an equity-focused and data-driven approach that supports aligning the urban and health agenda [60, 99–101]. Our latest data indicates that populations in the peripheral areas and the densely populated city’s east must invest disproportionately when commuting to radiotherapy services. This should challenge traditional urban and planning approaches and support actions to enhance social justice by focusing on health equity [60, 71, 96].

Our findings highlight the potential for dramatic improvements by strategically locating radiotherapy services in 1–2 new sectors that could optimise accessibility. Traditionally, radiotherapy services have been co-located with tertiary care emergency services, but none exist in Cali’s east (Figs. 1 and 2) [12, 56]. Recently, stand-alone centres have been developed elsewhere, prompting consideration of whether Cali should have a tertiary care

hospital(s) in the east offering comprehensive radiotherapy services or if stand-alone centres are more suitable.

If decision-makers add services in a single area, La Base or its surroundings emerge as the optimal location to maximise accessibility (Figs. 8 and 11). These services must have the capacity to meet the high demand from the populations covered in their catchment area and remain accessible to all radiotherapy patients. Expanding capacity in the east could alleviate demand pressure on existing centres, freeing up resources to accommodate the needs of metropolitan areas and neighbouring communities.

This study draws attention to the “inverse care law” in radiotherapy services in Cali, mirroring patterns seen in tertiary care emergency services and haemodialysis [12, 36]. Such a higher impact on vulnerable populations exacerbates social injustice [102, 103]. Previous studies have suggested that residents in informal settings, like others facing vulnerability and inequity in accessibility, are more likely to be disconnected from formal transportation modes. Video testimonies (close captioned with automated translation) from Cali’s peripheric impoverished areas reveal compounding mobility and financial

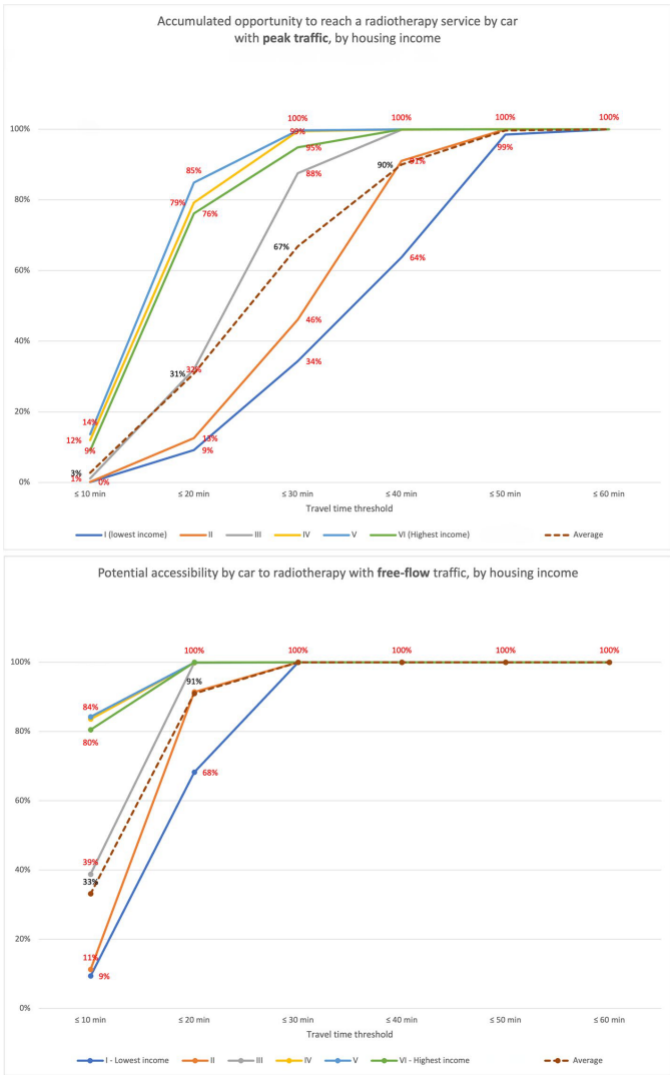


Fig. 7 Accessibility gradients by housing economic stratum with peak vs free-flow traffic (6–12 July 2020)

challenges residents face trying to reach a paved area where private or hired drivers can pick them up to attend ambulatory services requiring frequent use, such as cancer treatments. They describe incurring catastrophic

health expenditure and losing their autonomy. In addition to prolonged travel times, they may need help getting to where they can be transported to the service and still struggle to find suitable vehicles and the means

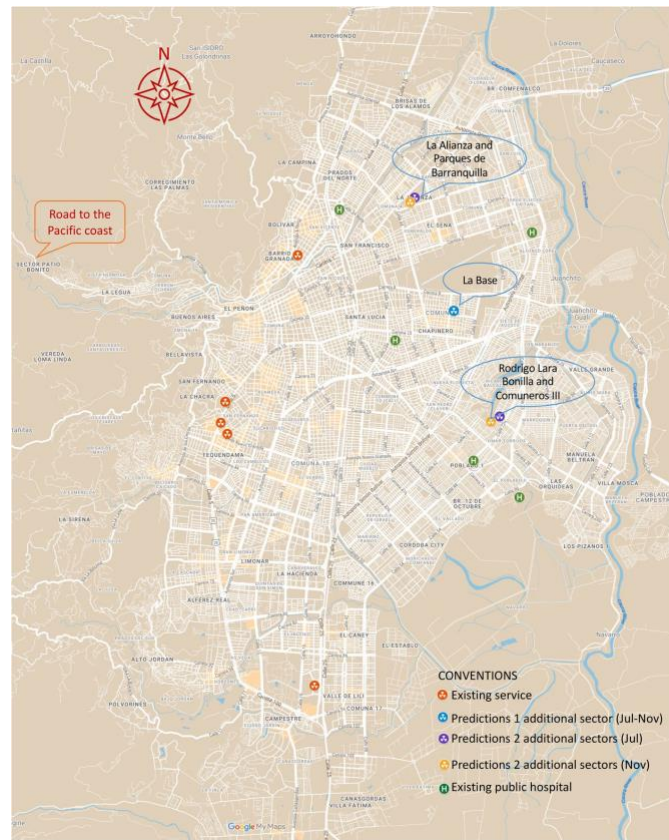


Fig. 8 Locations to optimise urban accessibility by adding services in one vs. two sectors

to pay for their long commutes [3]. These testimonies broaden our understanding of the social justice issues that sink families into poverty and the consequences of keeping these populations beyond the reach of suitable public transportation [42, 48, 49]. The contrast is striking against the well-off locations hosting radiotherapy services and offering cheap and convenient commutes for neighbouring populations. This study underscores the imperative of bringing services within a short journey of patients.

Since radiotherapy is an integral part of a comprehensive treatment, service providers should avoid fragmenting healthcare services to maximise accessibility and quality of care [54, 55, 104, 105]. Recognising that

radiotherapy capacities are strained, many individuals face long journeys to their service providers and that health services fragmentation makes things worse because they may not even be able to use the services with the shortest travel times, our findings are intended to encourage and inform societal agreements to improve accessibility to radiotherapy services [37, 53]. The challenges found in Cali likely extend to other cities in Colombia and beyond, amplifying inequities [90, 105]. The study's approach has the potential to assess and monitor such issues in various contexts and enable participatory urban planning with inputs from advocates and civic groups [37, 42, 44, 104, 106–109].

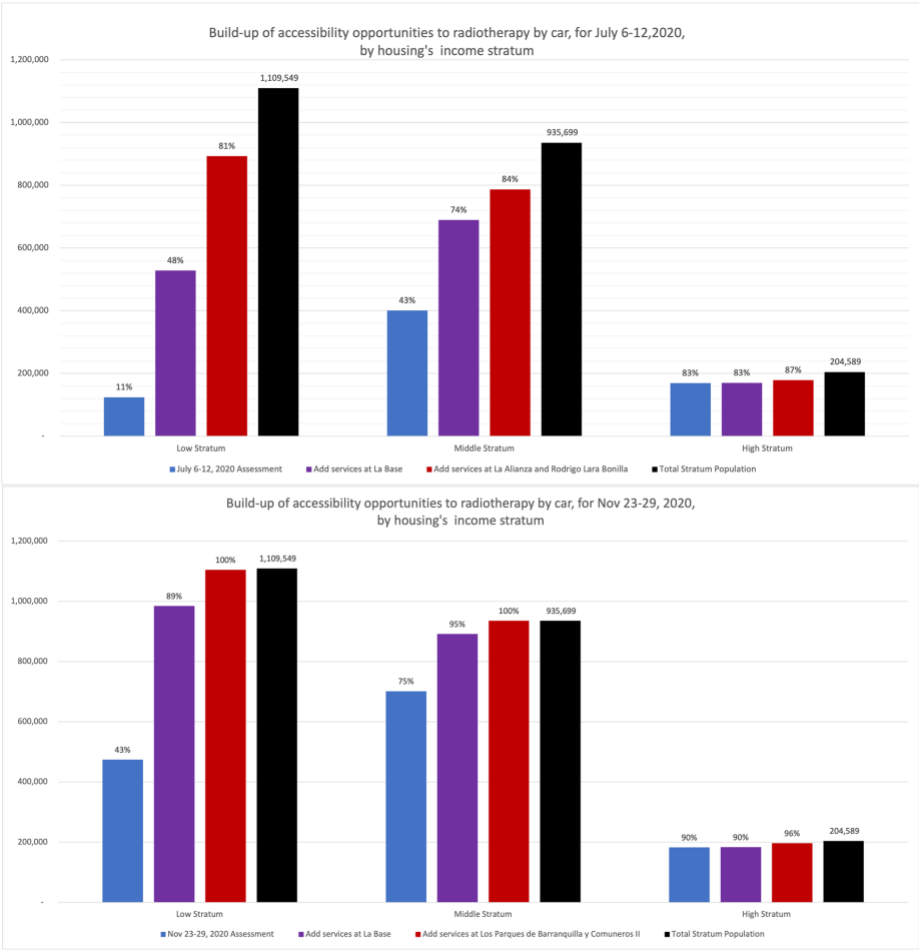


Fig. 9 Assessment and predictions for accessibility improvement by housing income stratum for two measurement periods

This study's approach opens avenues for implementing accessibility monitoring and evaluation, suggesting periodic (e.g., annual, semi-annual) assessments and exploring the economics of different approaches to enhance accessibility. For instance, by informing development plans, land-use and health services planning about adding services to existing public infrastructure, as tested in early AMORE web Platform prototypes, versus new infrastructure [77]. The expected release of projected census data in 2024 allows updating these findings and integrating this approach into urban observatory networks [110, 111]. This also presents a chance to promote community data initiatives involving intersectoral and multistakeholder collaboration. For instance, addressing the scarcity of data from informal settlements, popular neighbourhoods, or Cali's new districts to tackle health

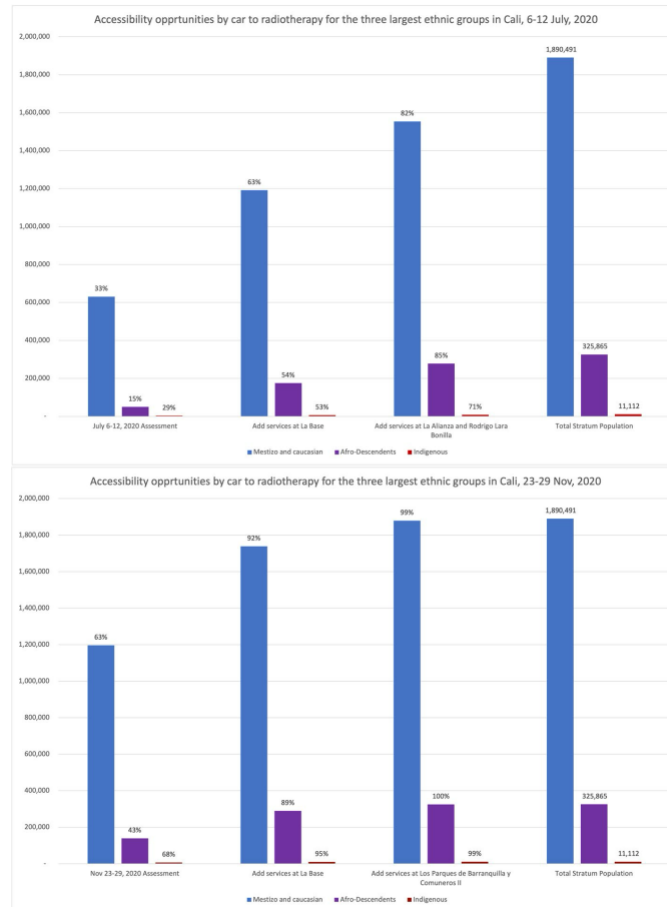


Fig. 10 Assessment and predictions for accessibility improvement for the three largest ethnic groups in Cali during two measurement periods

equity and social justice issues for populations that often lack agency and remain neglected [41]. Another opportunity for future development involves applying the approach to specialised radiotherapy services, such as brachytherapy.

Our findings emphasise the need to monitor demand, building on open and big data integration opportunities [30]. Epidemiological and economic studies could shape the services and capacities of new and existing radiotherapy facilities. Understanding current and predicted

radiotherapy needs and expected trends would benefit such deliberations.

Another practical application is calculating a fairer distribution of subsidies by adjusting them according to DSTAM. These measurements could be used to prioritise the organisation of mobility services for patients in outlying urban areas, and extended to cover metropolitan areas [63, 112].

Given the substantial expected demand that strategically located services could have, our findings underscore the urgent need for additional radiotherapy services

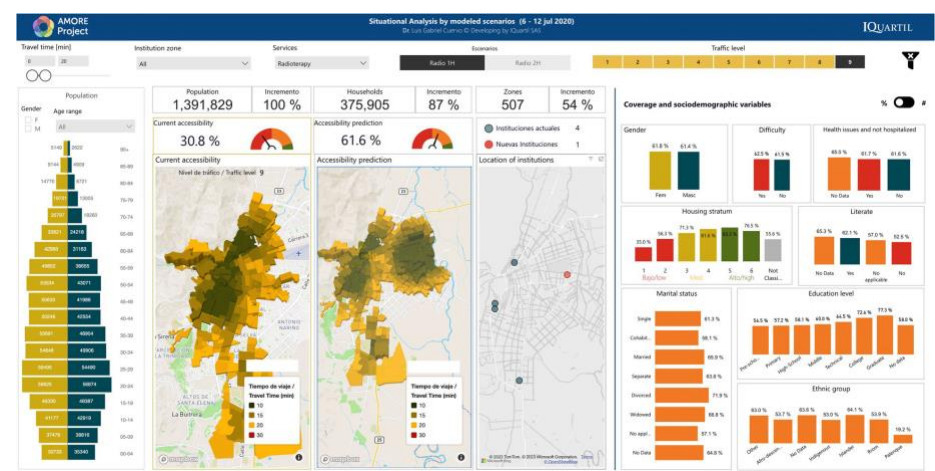


Fig. 11 AMORE Platform interface showing the relative effects of adding services in one location based on July data

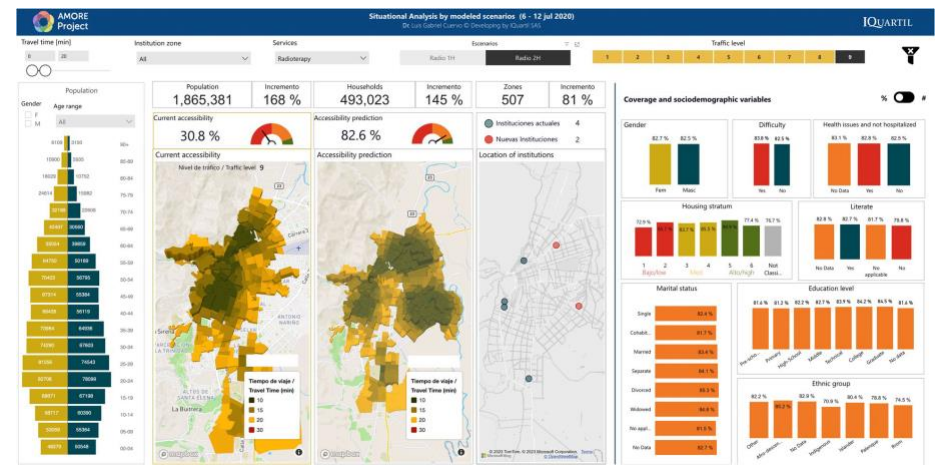


Fig. 12 AMORE Platform interface showing the relative effects of adding services in two locations based on July data

accessible to all residents. Our data provides insights and valuable parameters for health services planning and advocating for re-evaluating Cali land-use policies. Despite its limitations, the new methodological approach tested for tertiary care emergency services, haemodialysis, and radiotherapy reveals the potential for notable improvements to accessibility, social justice and health equity if services were added to Cali's densely populated eastern Aguablanca district. In this district, optimal locations for new services would optimise accessibility [12, 36, 80]. Whether that is done through concerted action for specific services or an integral approach

to improve multiple services at once (e.g., tertiary care emergency services, ambulatory treatments for high-cost conditions) is beyond the scope of this manuscript. The territorial distribution of existing services makes these findings unsurprising, and this study and the AMORE web-based interactive platform reveal the links between the population, the territory, and services, with cartography, measurements and predictions pertinent to public policy and urban planning.

Key results

The impact on health equity, as our findings show, is substantial and multifaceted. Our findings predict that accessibility could be quickly improved by adding strategically located radiotherapy services and allowing patients to access services offering the shortest journeys. That could transform accessibility opportunities throughout the city, foment new data-driven approaches, and spur further development and innovation to improve the quality of care [51, 53, 60, 101]. We found that it is possible to enhance peak-traffic accessibility levels to levels currently seen only with free flow or minimal traffic congestion. Our predictions point to solutions worth considering. We have informed stakeholders at every level of primary healthcare governance, enabling them to advocate, plan, and monitor [13, 21, 35, 38, 75]. These stakeholders include government, communities, service providers and users, opinion leaders, local leaders, academics, patient groups, scientists, and the media [23, 25, 35, 37, 38, 59]. Those entities actively engaged with this participatory research project are of particular significance [3, 22, 35, 113]. We encourage policymakers to explore strategies for fairer transportation subsidies by grading them according to accessibility.

Our evaluations could be replicated, perfected, and further developed with multistakeholder groups supported by data scientists to generate repeated geographical accessibility assessments for these and other services in urban and metropolitan areas where traffic congestion matters [12, 14, 30, 36, 37, 51, 53, 77, 101]. We encourage adopters of this approach to use relatable formats where the data speaks for itself and where stakeholders can test assumptions and scenarios for themselves and find that they can communicate these findings to their constituencies and partners [13–15, 18, 21, 23, 25, 108, 113–115].

This study provides a valuable analysis of accessibility opportunities within the Colombian health system. It also sheds light on a practical estimation of traffic congestion's impact on equity and accessibility. It is informative to stakeholders from diverse sectors (e.g., health, urban planning, smart city, economy) with a stake in urban and health services planning [27, 37, 53, 61, 100, 101].

Interpretation

These findings empower citizens to participate in data-driven dialogues with land-use and health services planners. The overarching goal is to facilitate necessary improvements, bridging the health equity gap and ensuring universal access to healthcare [116].

Care models for bustling cities should incorporate quality aspects of health services like travel times. This analysis is an opportunity to recognise that comprehensive care for radiotherapy patients is inherently linked to other services, including psychological support, rehabilitation therapies, nutritional guidance, pain management, or palliative care. Therefore, to ensure that patients can access services without suffering hardship, planners must organise to offer integral care within reach, including chemotherapy and other ambulatory services that can be combined with radiotherapy [52, 53, 55–57, 87, 104]. Future research and smart governance could monitor and optimise the distribution of treatments with an integral perspective to minimise travel and service fragmentation and to provide continuity with established integral cancer treatment teams [55, 104]. A refined version of the AMORE Platform could be used to monitor progress [51, 60]. Local governments could adopt strategic approaches and enhanced indicators for accessibility in cities with heavy traffic [53, 60].

In this context, balancing the advantages and disadvantages of centralising versus decentralising radiotherapy services is essential. The geographical segregation of populations in Cali (Fig. 2) and the concentration of scarce services in areas with low population density disproportionately reduce service quality for those populations already hindered by a broad array of social determinants of health and result in geographic exclusion [90, 117].

Radiotherapy services are concentrated in the area from the north-to-south corridor of Cali to the west end of the valley where the city lies, leaving eastern Cali uncovered (Figs. 1 and 2). Restrictions that prevent patients from accessing services available in every sector could further reduce accessibility. For instance, the Fundación Valle de Lili radiotherapy service, in the southernmost part of Cali, is the sole provider for the densely populated southern areas of the city. Suppose health maintenance organisations or insurers (EPS/EAPB, in Spanish) do not contract with providers close to patients or assign patients to distant services. In that case, patients won't benefit from services in their proximity. We consider that the low-accessibility and inequity gradients stress the urgency of implementing reforms to address the fragmentation of health service delivery.

Strategically adding radiotherapy services will benefit the overall population across all economic strata and

ethnic groups, with advantages for currently underserved groups (see Tables 1, 2, Figs. 8 and 10). Future studies could measure the direct and collateral economic impact of putting services within shorter travel times and distributing transportation subsidies with schemes that support social justice.

Colombian law requires the treatment of emergencies throughout the health system, reducing fragmentation. However, such a law needs to be put in place for ambulatory services for high-cost conditions, like radiotherapy; therefore, patients might be restricted from accessing conveniently placed IPSs [12, 118]. Colombia is undergoing a health reform, and assessments like this could provide insights for policy change, including free choice for radiotherapy providers.

We encourage readers to access the platform to test assumptions and scenarios. The interactive platform allows one to toggle or select specific radiotherapy providers. The platform can be accessed at <https://www.iqartil.net/proyectoAMORE/> with additional guidance at https://padlet.com/Proyecto_AMORE_Project/products [21, 98].

This and previous assessments done as part of the AMORE Project Collaboration's proof-of-concept show it is possible in LMICs to integrate open and big data to obtain dynamic geographical accessibility assessments for health services, providing an equity perspective and following recommendations to communicate findings to multiple stakeholders better [3, 12, 29, 36].

Generalizability

The availability of travel-time big data allows for assessing various transportation modes. This approach applies to a broad spectrum of services, provided georeferenced data is available.

Notably, international policies and mandates are accelerating digitisation and datafication trends in many countries [119]. This study's approach is transferable and can be replicated in other settings with traffic congestion, provided the essential data is available. Using population-weighted TAZ centroids instead of blocks reduces the overall costs associated with travel-time data while allowing for precise estimates [3, 36, 38, 89]. Like Colombia, other countries can harness available georeferenced open data of their population and services and integrate it with travel-time big data and TAZs to estimate ACOs [119, 120]. Travel-time big data is available from various providers. The resulting assessments could inform land-use and health services planning and contribute to aligning radiotherapy and other cancer treatments with universal health coverage [29, 121].

The public and private sectors can also adopt and refine this methodology by integrating information about population epidemiology, insurance providers, and payment agreements with health providers. These approaches are more complex and require investing in technology and participatory methods for stakeholder engagement. For example, integrating additional data might help identify the service with the shortest journey and availability for a specific appointment time. It might also guide insurers' prioritisation of providers to expand their coverage or reduce fragmentation. When patients can access services in every sector offering them, accessibility will reach the levels we measured. As we reported in this study, the benefits of obtaining more precise and sophisticated assessments should be carefully weighed against the required resources, considering the high-level evaluation feasible with reduced funding and in a short time.

Our methodology can be adapted to assess other transportation modes, services, and geographical areas. Such replication might involve downloading travel times for additional transport modes, adjusting traffic congestion models, population centroids within traffic analysis zones (TAZs), and refining predictive models [38].

While this study included approaches for promoting sectoral advocacy, social adoption and application of knowledge in health services planning, such assessments go beyond the scope of this report. Sustainability for these models can be achieved if travel-time metrics and monitoring become standard and a requirement in urban, health, and mobility assessments [53, 60, 101].

Limitations

This study seeks to identify the radiotherapy service with the shortest travel time. However, patients in Colombia are assigned to a health services provider institution (IPS in Spanish) under contract with the health promotion entity (EPS, in Spanish) or Benefits Plan Administration Company (EAPB) responsible for providing services to them [118]. It may result in reported accessibility rates exceeding the accessibility individuals experience, which will be lower when EPS affiliation limits a patient's access to the services offering the shortest travel times. We had no access to georeferenced data on EPS/EAPB coverage for populations; therefore, our findings show cumulative opportunities instead of actual accessibility. This fragmentation introduces a potential bias in our findings.

This report does not consider the characteristics of individual radiotherapy services, their capacity, or which ones offer specialised brachytherapy services, for example. It also does not integrate service agreements or georeferenced patient information. Therefore, our

assessment errs on being optimistic; it reflects those populations that, even in the best-case scenario, would be beyond the assessed travel-time threshold. It points out that addressing these issues may involve actions on different fronts, from adding services to addressing health services fragmentation to enable access to those services with the shortest journeys and providing an integral approach to cancer treatment where radiotherapy services are located. Nevertheless, it is possible to adjust for specific services by activating or deactivating services considered in the accessibility assessments in the AMORE Platform. For faster response, the published AMORE platform is set to identify locations that optimise accessibility with peak traffic [98].

Radiotherapy services are provided to the broader metropolitan area and neighbouring cities; this study focused on urban Cali. While the approach's efficiency relies on using open and big data, the accuracy of the findings depends upon the accuracy of these publicly available data sources. Inaccuracies in sources may render some estimations or conclusions inaccurate. We did not include cost-effectiveness analyses or accurate demand and capacity estimates for new services.

Conclusions

This study advocates for using DGAMs to monitor accessibility in cities where traffic congestion might be amplifying inequities and as conditions, infrastructure and populations change [122]. It also demonstrates that predictions suitable for integrating health with urban and territorial planning can be made using open data. The engagement of local stakeholders improved the platform and the pertinence of the analysis options and placed the focus on the needs of data end users and beneficiaries.

The study pragmatically approached the singularities of bustling urban settings with a holistic approach considering the stakeholders, tensions, and challenges of territorial and health services planning. It measures accessibility per traffic congestion gradients with an equity perspective. It offers a simple and robust approach, provides baseline assessments, and predicts the impact of interventions building on readily accessible open data and accurate travel time big data. The data and analyses used to reach the conclusions presented here are drawn from multiple research tools and methodologies, including cross-sectional epidemiological study, participatory research, and AI and data sciences. In using this approach, we have aimed to provide an integrative perspective built on a robust and diverse evidence base.

The potential of improving accessibility to radiotherapy services for many patients stresses the urgency of acting on these data. We recommend prioritising new integrated radiotherapy or cancer care services in Cali's

densely populated east, considering locations that maximise accessibility and health equity. Subsequent updates and evaluations will determine if adherence to integrated knowledge translation and social appropriation of knowledge principles lead to participatory urban and health services planning. They might also establish if services in eastern Cali will increase service referrals from the broader metropolitan area and neighbouring municipalities where radiotherapy is in short supply.

We sought the engagement and input of diverse stakeholders, including local government authorities and experts, health services planners, organised civil society groups such as academia and urban observatories, health service providers, health services user groups, and knowledge brokers [26, 27, 38]. The impact of such engagement differs from this report's focus [38, 78].

Integrating equity assessments into urban and health services planning is crucial in aligning urban and health agendas, and inequality monitoring is key to addressing the social determinants for health and promoting social justice [60, 109]. This approach can be refined and adapted for cities to improve data-driven planning and develop suitable indicators for monitoring accessibility when heavy traffic congestion is prevalent [40, 51, 60, 99–101, 123]. This study points to solutions to address traffic congestion's impact on social justice and health inequities. The new data can be used as part of an integrated strategic approach to advance SDGs (3, 9, 10, 11, and 17) in cities with heavy traffic and provide a baseline for Cali. The strategic approach used addresses calls made by United Nations agencies [37, 51, 99–101, 109].

Other information

Health services planners could further research the effects of people-centred participatory approaches with multistakeholder engagement to seek stakeholder engagement in shaping urban and health services planning and social justice. The AMORE Project interactive interface is publicly available, and stakeholders can assess diverse scenarios and parameters [21, 24, 35, 38, 74, 124].

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12939-024-02211-6>.

Supplementary Material 1. Reuse permission for the Populab participatory video documenting patient testimonies from Cali residents regarding commuting to health services for haemodialysis and cancer treatments from Commune 18—link <https://youtu.be/4fUgx7osKfw>.

Supplementary Material 2. GIF animation illustrating radiotherapy accessibility under different traffic congestion levels.

Supplementary Material 3. STROBE Checklist for cross-sectional studies.

Supplementary Material 4. Radiotherapy services identified through REPS under codes 711 (Radiotherapy as complementary or diagnostic treatment) and 408 (Outpatient radiotherapy).

Supplementary Material 5. CAC report for radiotherapy services, Cali, 2020.

Supplementary Material 6. Improving Radiotherapy Accessibility—AMORE Project <https://youtu.be/IQsGmbGWyZI>

Supplementary Material 7. Impact of adding services illustrated in three side-to-side slides.

Supplementary Material 8. AMORE Project Collaboration contributors.

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Authors' contributions

All authors approved the final draft submitted and agreed to be accountable for all aspects of this manuscript. Conceptualisation contributions: LGC, DC, JHR, and CJ. Methodological contributions: LGC, CJV, CJM, EMH, DC. Software: LGC, DC, PZ. Validation: LGC, DC, PZ, and CJ. Formal Analysis: LGC, DC, CJM, JM, AP. Investigation: LGC, EMH, CJM, MOB, GM, SMV, AP, MFN, ILM, CP. Resources: LGC and DC. Data curation: LGC, CJV, PZ, and CJ. Original draft writers: LGC, CJV, CJM, EMH. Draft review and editing: LGC, CJV, CJM, EMH, DC, PZ, MBO, SMV, AP, AS, MOB, JM, GM, DEC, NJO, FP, JHR, GDP, MFN, ILM, CP. Visualizations: LGC, CJV, DC, PZ, AS, CJM; Supervision: LGC, CJV, EMH, and CJM. Project administration: LGC and CJV. Funding acquisition: LGC.

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Availability of data and materials

Data sources are listed in the text, the protocol, and the project's websites. <https://www.iquartil.net/proyectoAMORE/> [98] https://padlet.com/Proyecto_AMORE_Project/products [114]. Datasets are available at reasonable request.

Declarations

Ethics approval and consent to participate

This observational study integrates anonymised coded secondary data sources from publicly available open records. Colombia's census microdata used in this study and the location of approved selected health services obtained from REPS are publicly available [126, 127].

The study protocol does not involve human subjects research and is considered "without risk" per Colombian law. The Commission on Ethics in Animal and Human Experimentation (CEEAH) of the Universidad del Valle in Cali and the Vice-Rector for Research, Universitat Autònoma de Barcelona (Ref: CEEAH-6100) cleared this project [38].

Travel-time data used by the AMORE web-based platform is available from OpenScience [July <https://doi.org/10.17605/OSF.IO/XDA87> and November <https://doi.org/10.17605/OSF.IO/FMU2X>]. The interactive web-based interface of the AMORE Platform used for this report is publicly available at <https://www.iquartil.net/proyectoAMORE/>. Readers can interact with changing

parameters and testing assumptions. A Padlet https://padlet.com/Proyecto_AMORE_Project/products offers access to the website, tutorials, databases, blogs, and presentations about the AMORE Project.

Competing interests

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1 Integrative discussion

This chapter integrates the three case studies, draws out their broader implications, and distils operational lessons from the AMORE Project.^{6,79,81,82,116,262} The work addressed the *primary objective* by co-developing, with interest-holders and data scientists, an interactive web platform that measures dynamic accessibility to selected health services in Cali and forecasts the potential gains from strategically adding capacity. In doing so, it incorporated traffic congestion and an equity perspective, employed big and open data, and delivered two measurement rounds for three tracer services without external funding. The availability of comparable data in many cities suggests both scalability and replicability.^{263–270}

In relation to the *assessment of temporospatial accessibility and equity*, the results reveal a pronounced amplification of accessibility differences as congestion increases, disproportionately burdening low-income and peripheral communities. The *dynamic assessments* generated by the platform enabled hour-by-hour comparisons under varying congestion levels. Analyses examining *vulnerable populations* consistently showed greater disadvantage among residents of lower housing strata, Afro-descendant communities, and those with lower educational attainment. Comparing *equity-oriented patterns* across two pandemic moments confirmed that mobility shifts differentially affected these groups. Overall, traffic congestion significantly reduced both total and disaggregated accessibility, highlighting its central role as a determinant of urban health equity. Finally, *modelling of potential improvements and optimal locations* indicated that adding sufficient capacity for tertiary emergency care, haemodialysis, and radiotherapy—particularly in the east and northeast—would raise peak-hour accessibility towards off-peak levels and place most residents within short travel times of essential services.

These findings have direct implications for planning. The eastern districts, home to roughly half of Cali's population, require tertiary emergency capacity capable of

meeting demand within clinically relevant thresholds throughout the day; otherwise, the inverse care law will continue to perpetuate exclusion.^{271,272} Scenario testing with alternative thresholds can support evidence-informed decisions that balance clinical requirements, user preferences, and urban constraints. The approach has already informed the city's 2024–2027 Development Plan and land-use deliberations.

116,128,256,257,273,274

Methodologically, the project synthesised good practices across domains to assess, forecast, and potentially monitor metropolitan accessibility. Twelve citywide measurement exercises (three services, twice each) achieved notable efficiencies through intersectoral collaboration, with hourly observations over two weeks covering 30 services across 15 TAZs for car travel.^{79,81,116,241} This aligns with calls to integrate urban and health agendas, including WHO's Strategic Approach to Urban Health, and positions AMORE as a benchmark case for developing congestion-aware, equity-focused metrics.^{7,10,37,49–51,80,83,84,91,156,211,275,276}

Across services, common patterns emerged: marked inequities and clear scope to mitigate them by adding well-sited capacity. The findings stress the risks associated with service fragmentation as a potential barrier in Colombia's current reform discussions, as patients frequently travel across the city for complementary care.^{79,81,116,277–285} By diagnosing the problem dynamically and demonstrating feasible solutions, the work provides a scalable approach to narrowing equity gaps rooted in congestion and urban segregation, thereby strengthening the technical basis for local planning and universal health coverage.

Looking outward, dynamic accessibility assessments can accelerate the Sustainable Development Goals (SDGs) by linking local action to global commitments: improving coverage and equity (SDG 3 and SDG 10), informing infrastructure and transport (SDG 9 and SDG 11), contributing to climate mitigation and sustainable mobility (SDG 13), and fostering transparent decision-making and partnerships (SDG 16 and SDG 17). The same architecture can guide fairer distribution in other sectors (for example, nutrition, education, or justice). See Annex 8.14 for relevant indicators.^{7,37,286–289}

By operationalising the categories later included in WHO's Strategic Approach to Urban Health, the thesis project anticipated and contributed to the advancement of its application and was chosen as a case study to illustrate its application.^{6,7,10,49–51,207}

1.1 Limitations and overcoming them

Several limitations were identified in our supporting articles and during the implementation process. Many could be addressed as the methodology and tools evolve, new data layers are integrated, and ongoing health reforms advance.

A first consideration is that our estimates reflect *potential* rather than realised accessibility. Residents do not necessarily use the nearest service within a given travel-time threshold. Structural and behavioural factors—such as insurer contracting, workplace proximity, provider reputation, or carers' preferences—often shape choices. This is particularly relevant for frequently used ambulatory services like haemodialysis and radiotherapy. Consequently, the model may overestimate effective accessibility. Its accuracy will improve as health-service fragmentation diminishes and empirical correction factors become available.

Complementary services, including nutritional or psychosocial support, are not always co-located within the same Traffic Analysis Zone (TAZ). The project's evidence and methods can subsequently be applied to identify such gaps and inform co-location policies. Emergency services function differently because Colombian legislation mandates unrestricted access to life-threatening conditions; yet even there, users may bypass the nearest facilities.

Round-trip conditions for ambulatory care differ by direction and time of day, yet our analyses only measured outbound car travel.^{68,133,135} While car use was contextually appropriate for the case studies, broader implementation should consider other modes, costs, and user preferences, ideally with more detailed sociodemographic

disaggregation.^{6,131–133,251} Future studies could examine full commuting patterns and the characteristics of necessary complementary services.^{95,98,108,117–119,284,290–294}

Our analyses used place of residence as the journey origin. Further work could identify alternative points of departure, such as workplaces or likely places where tertiary emergencies occur.^{295–298} Extending the analysis to the wider metropolitan region could refine recommendations, although results consistently highlight the need for additional capacity in the east, northeast, and Aguablanca districts and neighbouring municipalities.

Traffic patterns have changed since the data collection period.²⁹⁹ Although the pandemic has ended, Cali remains among the most congested cities in Latin America. Regular reassessment is therefore necessary. Technology transfer and local appropriation were only partly achieved, limiting the city's capacity to conduct ongoing analyses. Nonetheless, continued collaboration with civic and professional partners—such as ProPacífico and City Cancer Challenge—has fostered dialogue on travel times as a determinant of accessibility, which is encouraging for future uptake.²¹³

Progress will remain limited without agreed-upon metrics and standards that link congestion, accessibility, and equity, formally embedded in urban policy frameworks and high-level intersectoral agreements.^{57,76,169,275,300–304} Despite a growing body of work on dynamic accessibility, few studies are accessible to non-specialists or co-produced with knowledge users and interest-holders.^{19,20,44,66,67,69,71,72,168,234,245,248,249,267,269,305–315}

This research drew on implementation-science principles, adopting a pragmatic, real-world approach to intersectoral planning.^{12–15,29,55,191,238,316–319} Reporting followed established frameworks, including StaRI for implementation studies;³²⁰ STROBE-Equity and PROGRESS+ for equity reporting;^{83,84,321,322} SQUIRE for quality improvement;³²³ GRIPP2 for public involvement;^{320,324} and TiDieR for intervention

description and replication.³²⁵ The expanding availability of big and open data makes this a timely moment for scoping reviews to consolidate emerging methods.^{4,18,92,164,169,270,300,326–328} Economic analyses are also necessary to link accessibility gains to the direct and indirect costs incurred by patients, families, providers, and systems due to service segregation.^{108,119,170,294,329}

The methodology was tested within Cali’s urban area, although the city functions as a referral hub for Colombia’s Pacific region. Broader assessments could inform regional planning and redistribution of services. Our most recent prototypes introduced several improvements; however, limited funding prevented us from maintaining a function that compared the effects of adding new versus upgrading existing facilities—a valuable feature for future iterations.

Implementing change will also require further engagement with planners and providers, as many still rely on distance-based metrics or underestimate the implications of congestion. Some attempts to add new services failed because they were sited near existing ones or constrained by zoning regulations. Scaling up will require institutional backing, data clearinghouses, and standardisation efforts that multilateral organisations could champion.

“This is not just another proposal aimed at public policy decision-makers—of which there are many, and of great quality. This is an exercise that, because it can be easily used by anyone and updated or replicated without major limitations, not only has a high persuasive power, but is also highly useful for health service providers—often private entrepreneurs—as it helps them offer better care to their patients while maximising the efficiency of their operations.”

Felipe Piquero, collaborator, lawyer, author of an autopathography, and a recurrent user of the analysed health services.- Padlet/Multimedia⁽¹⁴²⁾

The validity of our estimates depends on the consistency and periodic updating of underlying data. Census and travel-time data must be updated to capture demographic and infrastructure change.^{230,330–336} TAZ boundaries, seldom revised, should evolve with urban development. Although these factors may not substantially alter our conclusions, they underscore that the results reflect a specific point in time.

Traffic heterogeneity also requires local calibration; in fourteen cases, we adjusted TAZ congestion levels to maintain internal consistency.

While available empirical evidence and widespread application indicate that the Google Distance Matrix API yields plausible travel time estimates and is used to calibrate other algorithms, the proprietary nature of its methods renders its internal functioning largely inscrutable. As a result, researchers have limited insight into how large-scale mobility data are processed, calibrated, and validated, which constitutes an inherent limitation when relying on such big data sources for scientific inference.^{5,99,309,337–339}

A distinctive strength of this study is its ability to translate complex analyses into policy-ready formats. Colour-coded choropleth maps can reflect specific targets—such as achieving 95% accessibility during peak congestion—and the interactive platform allows users to test alternative thresholds rather than relying on a single cut-off.^{79,81,82,116} Few comparable studies combine congestion and equity analysis with participatory co-development and identification of optimal service locations.^{10,27,28,43,56,66,75,91,95,169,174,177,180,187,191,197,249,306,312,318,340–364} These features make the evidence actionable for decision-makers.^{9,10,25,212}

Engagement with interest-holders enhanced the relevance and impact of the work, though such collaboration is context-dependent and difficult to replicate. It relies on trust, local experience, and power dynamics that cannot be reduced to formulae or reproduced mechanically.

“The project offers a replicable and adaptable tool, tested in the reality of Santiago de Cali, that is already guiding better decisions about where key services should be placed to serve people better.” Felipe Piquero, collaborator, lawyer, patient advocate, and author.

1.2 Future directions and ongoing contributions

The three manuscripts in the Core Compendium report the main findings from each case study.^{79,81,82}

Predictions for tertiary emergency care, excluded from the papers due to word limits, were developed in an invited manuscript that integrated results from the three analyses. This work modelled potential improvements from strategically locating new services in one or two TAZs to optimise citywide accessibility for haemodialysis and radiotherapy. Peer review at the *International Journal for Equity in Health* recommended dividing the paper to expand methodological detail, leading to plans for two separate submissions—one focused on tertiary emergencies and another integrating findings for chronic care.¹¹⁶

Publishing intersectoral work proved challenging. Although some journals welcome such studies, their review processes often require expertise across multiple domains—public health, urban planning, data science, mobility, and policy. Editors frequently struggled to find reviewers confident across these areas, leading to extended timelines. Many declined review invitations, citing unfamiliarity with aspects of implementation research or science communication.³⁶⁵ Nonetheless, journals that ultimately published our studies demonstrated openness and constructive dialogue, validating both our findings and methods. This experience, discussed further in Chapter 1.4 below, underscores the importance of journals in strengthening editorial guidance and reviewer networks for intersectoral research.

Beyond these articles, new opportunities have emerged. Routledge and INTalInc-LAC selected the AMORE Project for inclusion in a forthcoming book, and the World Health Organization published it in December 2025 as a case study of its *Strategic Approach to Urban Health*.²⁰⁷ Additional work presented to the Colombian Nephrology Association in 2025 built on AMORE data with extended equity analyses.⁹¹ Collaboration also continues with civic and professional organisations—including ProPacífico and City Cancer Challenge—to apply project findings in real-world planning and operational contexts.²¹³

The data continue to reveal the profound spatial segregation that shapes accessibility in Cali. Roughly half of residents live in low-income housing, two in five in middle-income housing, and fewer than one in ten in affluent areas. Tracer services remain concentrated in high-income, low-density districts, while large populations in the eastern Aguablanca sector lack them. Historical insights from collaborating social scientists reveal that many of these neighbourhoods arose from informal settlement on land exposed to seismic and flooding risks, following displacement from Colombia's Pacific coast and subsequent migration from Venezuela. Over time, legalisation processes have enabled the provision of basic services but not yet the specialised ones analysed here.²²⁹

Despite the expansion of first- and second-level hospitals and community centres through programmes such as Desepaz, tertiary emergency, haemodialysis, and radiotherapy services remain scarce in the east, northeast, and Aguablanca (Map 2). Other low-income areas—such as the western slopes of Siloé and Terrón Colorado—and even the affluent yet isolated neighbourhoods of Pance also face long travel times due to limited road access and public transport. Across all three case studies, traffic congestion further amplifies these inequities, disproportionately affecting residents of lower socioeconomic status, Afro-descendant communities, and those with limited education.⁷⁹

Nonetheless, the projections generated through the AMORE Platform offer cause for optimism. By strategically locating additional services, particularly in Aguablanca and the northeast, urban accessibility for all three tracer services could improve substantially, delivering the largest equity gains. These ongoing contributions expand the reach of this research and reinforce the integrative discussion presented in the following section.

1.3 Implementation Research recommendations from running the AMORE Project

Drawing on five years of implementation, this section synthesises empirical lessons to inform future people centred and cross sector research initiatives. These insights derive directly from the design, testing, and scaling of the AMORE Project, and reflect its collaborative, adaptive, and participatory character. Elements of their implementation are documented across project reports, presentations, and audiovisual materials, and are also evidenced throughout the project's development.⁹³

1.3.1 Groundwork and Planning

- Begin with a clear theory of change and map the skills, capacities, and lived experiences (accessing tracer services) required to address project's objectives.
- Engage key collaborators early—knowledge users, service providers, patients, and other interest-holders—and mentor junior team members.^{13,184,366–368}
- Establish robust support systems for science communication, project management, and continuity to ensure sustainability during transitions or unforeseen challenges.^{159,160,330,336}
- Consider good practices and research reporting standards from the outset. For example, understanding the requirements for reporting equity in observational studies can help shape the entire research process, from design through analysis to dissemination.^{322,369}

1.3.2 Strategic Communication

- Develop a communication strategy that promotes coherence, transparency, and inclusion.

- Use accessible tools (such as Slack, WhatsApp, Zoom, and Miro) and culturally appropriate multimedia formats (videos, infographics, and plain-language materials).
- Test and refine messages with diverse audiences, maintaining regular and participatory communication.

1.3.3 Engagement and Advocacy

- Anchor research in existing policy frameworks and shared societal values.
- Present concise previews (e.g., animations, one-pagers, or infographics) to engage partners and informants.
- Integrate lived-experience testimonies into policy dialogues, ensuring that beneficiaries' voices inform decisions.
- Stay focused on core goals while navigating external agendas and institutional priorities.

1.3.4 Cross-Sectoral Learning

- Encourage participation across disciplines and adapt terminology to different professional and community audiences.
- Facilitate direct interaction between data scientists, communicators, project managers, and decision-makers to promote shared understanding.
- Support research that explores mobility, inequities in accessibility, economic costs, gendered patterns, and behavioural factors influencing access.^{34,75,76,79,169,226,234,326,340,370–372}

1.3.5 Sustainability and Amplification

- Empower collaborators to act as ambassadors and share ownership.
- Prioritise open access and multimedia outputs to ensure reach and equity.
- Balance ambition with context—replication depends on social conditions and timing within policy cycles.

- Build knowledge-action networks (e.g., across Latin American cities) to share metrics, align urban and health planning, and sustain momentum.
- Share ownership by empowering collaborators to act as ambassadors and champions of the work.
- Prioritise open-access and multimedia outputs to promote equity and reach.
- Balance ambition with context—replication depends on local conditions, resources, and timing within policy cycles.
- Foster regional knowledge-action networks, particularly across Latin American cities, to exchange metrics, align urban and health planning, and sustain momentum.^{68,75,76,91,136,152,161,172,248,250,263,277,300,315,373–387}

Together, these lessons encapsulate the internal learning derived from implementing and scaling the AMORE Project. Section 1.4 below presents targeted recommendations for policymakers, service providers, civic organisations, communities, and researchers, helping diverse knowledge users apply and adapt these insights to strengthen accessibility, equity, and intersectoral action within their own contexts.

1.4 Recommendations and actions for impact¹¹⁶

These lessons from implementation research draw on the internal experience of designing, testing, and scaling the AMORE Project. They demonstrate how accessibility can be measured while considering traffic congestion, and how such evidence can be mobilised to reduce inequities and improve planning.¹¹⁶

Building on this foundation, this chapter looks outward, presenting recommendations for different knowledge users—policymakers, service providers, civic organisations, communities, and researchers. Each set is tailored to its audience, offering practical guidance on applying and adapting these insights to strengthen accessibility, equity, and intersectoral collaboration. The collaborative group has continued its advocacy, has additional publications in the pipeline, and has established partnerships, giving continuity to the project. As new synergistic

studies have emerged, we have engaged with authors to share knowledge and promote collaboration. This is also reflected in the growth of the project's LinkedIn page, which by the end of 2025 had 2253 followers, including many such authors, leaders from relevant organisations, and interest holders from diverse sectors, disciplines, and governance levels.

1.4.1 For policymakers

- Integrate accessibility needs into metropolitan and regional planning instruments, aligning with health reforms.
- Collaborate with communities, sectors, and providers to place new services strategically within the current administration (e.g., 2025–2026).
- Introduce transport stipends tied to travel-time assessments, targeting support to populations facing the longest or most complex journeys while reducing subsidies for those with convenient local access.^{98,110,113,118,290,388–390}
- Use cartography and dashboards to visualise accessibility and mobilise cross-sector campaigns toward universal access (e.g., the “paint our city green” concept).^{116,247,391}
- Legislate for service integration, ensuring comprehensive and conveniently located healthcare.
- Establish monitoring and evaluation systems to track accessibility for health and other essential services (e.g., food security, education, legal aid, emergency response).^{113,196,249,270}
- Evaluate the impact of adding services for suburban and rural populations alongside metropolitan centres.
- Broaden assessments to cover diverse transport modes and regions.
- Advance standardisation, clearinghouses, and agreements to sustain future developments.

1.4.2 For service users, providers, and advocates including non-government organisations

- Advocate for a whole-of-government and societal approach to mitigate traffic congestion's effects on health equity.^{44,68,102,191,392}
- Demand actionable data and participatory processes that enable coordinated policy responses for health justice.^{10,13,27,55,186,187,198,341–343,347} A recent example: in April 2025, City Cancer Challenge and ProPacífico convened a workshop to improve data science applications for breast cancer diagnosis. Similarly, the DS4A included a call from Colombia's Ministry of Technology for follow-up by the National Department of Planning.^{213,224,393}
- Adapt participatory processes and tools to raise awareness among populations that are often neglected or excluded.
- Apply and adapt AMORE methods to monitor accessibility in other cities and services.^{50,79,116,247}
- Explore integration with health system operations—for example, linking travel-time data with appointment systems or insurance to improve access to convenient slots.^{116,209,394}
- Leverage Cali's new status as a Special District with decentralised local administrations as an opportunity to address service segregation and use data for more equitable distribution.^{126,395,396}

1.4.3 For urban observatories

- Integrate urban observatories with digital monitoring platforms, linking accessibility metrics to equity.
- Promote data-driven planning and policies in congested urban environments.
- Streamline data integration and ensure flow toward observatory dashboards.
- Support evidence-driven metropolitan and regional decision-making on accessibility.

1.4.4 For research teams and sponsors

1.4.4.1 Intergovernmental organisations, multilateral institutions, and philanthropic entities

- Support open-source, equity-focused platforms and dashboards to monitor and improve accessibility in congested cities.^{3,4,9,51,75,246,300}
- Promote standards, norms, and best practices while advancing digital public goods.^{397,398}
- Establish data clearinghouses for metropolitan and regional accessibility analyses.²⁶³
- Sponsor implementation research integrating accessibility into health planning.
- Call for harmonised metrics of accessibility that reflect equity and universal health coverage goals.^{37,57,399}
- Develop practical checklists to guide working groups and assessments in adapting or replicating this approach.⁴⁰⁰
- Facilitate research agenda-setting and creation of regional public goods through partnerships with governments and organisations.^{42,44,67,70,401}

1.4.4.2 Research institutions and academic teams

- Advance implementation research and social innovations that address policy issues holistically.^{12,13,55,143,145,238,317,402–404}
- Organise interdisciplinary research on policy translation, economic analyses, and methods to improve service accessibility.^{67,72,76,77,110,121,169,171,184,300,372,405–408}
- Explore economic impacts across levels: patients (out-of-pocket costs), providers (satisfaction, costs), and society (equity, coverage, complications, quality of life).^{67,72,91,110,171,300,405,406,408,409}
- Conduct policy-relevant scoping reviews assessing accessibility, traffic congestion, and equity.^{44,58,68,69,92,168}
- Align international urban health and mobility agendas (e.g., Bloomberg Philanthropies, WHO, UN-HABITAT) with local equity goals.^{10,37,50,51,53}

- Create incentives for cross-disciplinary research addressing public policy challenges.^{12,13,55,402}
- Study local economic implications of poor accessibility and test virtual services to reduce travel needs.
- Use interactive, participatory resources to model space-time links and scenarios in formats usable by decision-makers and communities.

1.4.4.3 *Research reporting and review*

To address these challenges more systematically, journals and reviewers can play a pivotal role. Recommended actions include:

1.4.4.3.1 For journals

- Establish cross-disciplinary reviewer pools that include not only disciplinary experts but also *networkers* (akin to knowledge brokers or boundary spanners) who can connect perspectives across fields.
- Develop structured guidance for editors and reviewers on how to handle manuscripts that cut across multiple sectors.
- Recognise and value *partial yet complementary reviews* so that no single reviewer is expected to cover the entire scope of an intersectoral manuscript.
- Encourage editorial teams to adopt a constructive, dialogue-based approach with authors, as our positive experiences demonstrated this can be both feasible and beneficial.

1.4.4.3.2 For reviewers

- Contribute insights in their areas of strength without feeling compelled to cover all aspects of a complex manuscript.
- Embrace a collaborative ethos, trusting that colleagues from other fields will provide complementary perspectives.
- Where possible, act as *networkers* by helping to bridge disciplines, situate findings within broader debates, and link evidence with policy and practice.

Such measures would not only expedite the review process but also ensure that intersectoral work is fairly assessed and published.

Beyond the publishing sphere, strengthening the reporting and review of intersectoral research is crucial for advancing equity-oriented urban health and health services planning, addressing the social determinants of health, and achieving the Sustainable Development Goals. These goals inherently require working across sectors, developing partnerships, and generating evidence that can inform policy questions, which, by their very nature, demand bridging between disciplines and fields of knowledge.^{9,175,188,191,351}

This trajectory also resonates with the mission of the doctoral programme in Biomedical Research Methodology and Public Health, which seeks to advance methodological excellence in biostatistics and epidemiology and apply these disciplines to population health, health systems research, and the evaluation of healthcare quality. The AMORE Project and this thesis illustrate how rigorous methodological approaches can be combined with intersectoral, equity-oriented perspectives to generate policy-relevant evidence, offering a practical example of the kind of scholarship the programme aims to foster.

1.4.4.4 Training and education

- Promote a people-centred, multi-interest-holder approach to research on social determinants.
- Support education and training in implementation research and participatory methods that identify actionable, context-specific solutions.⁹

1.5 Core Contributions

- **Revealing territorial inequities and solutions** – Identifies underserved populations, maps accessibility gaps, and models improvements from strategically adding services.

- **Supporting intersectoral decision-making** – Provides actionable data and visual tools to engage civic organisations, providers, patient advocates, and authorities in joint planning.
- **Influencing public policy** – Informed Cali’s land use and development plans, positioning equity and accessibility as policy priorities.
- **Fostering social innovation and participation** – Convened diverse actors in co-developing and implementing tools, enhancing ownership and impact.
- **Enabling monitoring and evaluation** – Created scalable, low-cost, equity-sensitive indicators to support both real-time assessment and long-term planning.

By articulating open and big data with participatory people-centred approaches, the AMORE Project demonstrates how health equity and accessibility can be measured, modelled, and meaningfully improved. Its lessons extend beyond Cali, offering adaptable strategies for other cities facing congestion and inequities. The project’s ongoing momentum—fuelled by intergovernmental organisations, civic actors, and researchers—underscores its potential as a scalable public good for advancing sustainable and equitable urban health.

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2 Conclusions

Co-designing the platform with collaborators and incorporating inputs from knowledge users, interest holders, and key informants strengthened its relevance and accessibility, as well as the advocacy capacity of participating actors, thereby promoting local appropriation of the findings. This participatory and intersectoral ethos was essential for bridging evidence with decision-making and for ensuring that the tools developed were not only technically robust but also meaningful and applicable to policy and practice.

This thesis functions as implementation research by generating context-sensitive, co-produced, and policy-relevant evidence that decision makers have demonstrably taken up. Its citation in policy documents is not incidental; rather, it reflects outcomes consistent with its implementation-oriented design and intent.

Building on this foundation, the thesis demonstrates that travel times, particularly when adjusted for traffic congestion, provide a realistic and intuitive measure of accessibility to healthcare services in urban environments. Although people naturally describe journeys in terms of travel time and often consider congestion, planning systems have yet to incorporate these perspectives, despite the growing availability of open and big data that make such applications feasible. The analyses in Cali confirm that it is both technically and economically viable to generate citywide dynamic accessibility assessments using existing data, and that presenting this evidence through intuitive interfaces and an interactive platform enhances its value for policy and planning.

These assessments reveal substantial inequities in access to essential services such as haemodialysis, radiotherapy, and tertiary emergency care, underscoring the structural limitations of a segregated city where critical health services are disproportionately concentrated in low-density areas. This spatial imbalance reflects broader patterns of social injustice and planning bias that systematically disadvantage populations in densely populated or underserved zones. Importantly,

the thesis also demonstrates that these inequities are not immutable: the interactive platform enables the estimation of potential optimisation scenarios, informs debates on healthcare fragmentation and disconnectedness, and shows that strategically locating services to make them accessible to all residents would markedly reduce disparities. Populations experiencing vulnerability who require frequent or urgent treatment often bear a disproportionate travel burden, which is further exacerbated during periods of peak congestion. Whereas static measures tend to obscure these inequities, dynamic temporospatial analyses offer a more accurate and policy-relevant understanding of accessibility.

The methods developed here are transferable beyond Colombia, as comparable data are increasingly available in countries. This scalability reinforces the multicentric relevance of the work and its potential to inform international policy agendas. The findings also contribute directly to the monitoring and advancement of several SDGs. By advancing dynamic, equity-focused measures of accessibility within a participatory framework, this thesis supports global efforts to foster healthier, fairer, and more resilient cities.

This project therefore makes a novel contribution that is directly relevant to the objectives of a doctoral programme in biomedical research methodology and public health. It advances methodological innovation by integrating dynamic accessibility metrics with participatory approaches, while also responding to pressing local needs in Cali and Colombia. The timing is particularly auspicious, as the city's new political divisions and the formulation of the 2024–2027 Development Plan, alongside revisions to the land use plan, create immediate opportunities to translate the findings of this thesis into policy and practice. This alignment highlights the value of the work for harmonising urban and health services planning. At the same time, the methods and tools are transferable and scalable to other urban contexts worldwide, thereby supporting the achievement of the SDGs. In doing so, the project exemplifies how rigorous methodological research can generate practical solutions that address

inequities in healthcare access, inform decision-making, and contribute to building more equitable and sustainable societies.

In short, this thesis demonstrates that accessibility can be accurately measured when traffic congestion is accounted for, and that doing so provides robust, actionable evidence to reduce inequities, align urban and health services planning, and build healthier and fairer cities.

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2.1 Approved protocol – publication

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Optimization analysis using predictive and prescriptive analytics for modelling. Using heuristic techniques, the research will predict accessibility with different service schedules or when adding up to two new services in locations that maximize accessibility. Case studies will focus on hemodialysis and radiotherapy, which are used to treat high-cost conditions and must be accessed repeatedly for prolonged periods. For example, hemodialysis usually requires 3-5 weekly sessions, and radiotherapy may require daily sessions for weeks. Predicted accessibility with new services will be compared with measured accessibility (Figure 3).

Preparation for the project

Beginning on 12th June 12 2020, interviews were conducted with key informants, local authorities, and experts to inform the project, assess feasibility, and develop a protocol. They provided verbal consent to participate. These interviews offered contextual insights and ideas for the AMORE Platform to address the needs of data users and stakeholders. Discussions helped identify contributors and provided valuable contextual information. They also revealed how stakeholders approached health equity and accessibility and the relationship to urban and health services planning and land use. Stakeholders offered insights into the elements and processes of urban and health services planning, public policy, and advocacy.

Interviewees included:

- Members of the **SIGELO Project** on vulnerability, accessibility, and logistics in the context of the COVID-19 pandemic, Universidad del Valle
- Health equity and public health experts at the Bruyère Institute, University of Ottawa
- Contributors to Cali's Administrative Department of Municipal Planning (DAPM)
- Advisors and staff working with Cali's local government, including the secretariats of Health, Mobility, Urban planning, and Emergency response and preparedness.
- Data Science for All Team33 and IQuartil SAS analysts.
- Former local government and education authorities
- Urban observatories, urbanists, and networks on urbanism, mobility, and public health.
- Innovators and advisors working with health services and systems
- Service providers, including managers and science advisors
- Health services and accessibility data users
- Doctoral and professional networks
- Designers, graphic and science communications professionals, and artists
- Researchers and research sponsors.

Overall, 28 meetings were held with key informants and stakeholders between July 2020 and March 2022, when the advanced prototype of the AMORE Platform was completed. Like every doctoral thesis, this project is subject of yearly follow-up reviews by the Commission of the Doctoral Program on Research Methodology for Biomedical Research and Public Health of the Universitat Autònoma de Barcelona, since October 2020.

During the preparatory phase, the project was also debated in international fora such as the Global Health Learning Network of the University of Ottawa, The 4th Urban Forum "Lima Cómo Vamos," the CEDEUS-REDEUSLAC II International Symposium of Doctoral Candidates on Urban Development and Sustainability for Latin America, and the Caribbean (Chile), and with urban observatories (Cali, Bucaramanga).^{89,98,99}

These interviews shaped the AMORE project and platform. The objectives and platform were discussed from a theoretical perspective. Once the prototypes of the AMORE Platform became available, tests and demonstrations were made as part of the validation.

Data downloads and sources were stored in a dedicated repository using CSV formats to adhere to data sharing and reuse good practices. They will be made public with the publication of relevant research reports. Similarly, the AMORE Platform hosted by IQartil SAS is made accessible with the completion of non-disclosure agreements. We expect to make platform sections publicly available as relevant results are published.¹⁰⁰

Fidelity/adaptation

The fidelity of the AMORE Platform is based on data validation and verification exercises, comparing the findings from the AMORE Platform using the two data downloads and the two development teams.

The results of the platform will likely be optimistic for several reasons. For example, people do not always travel to the service with the shortest journey for known (e.g., lack of coverage from the insurance in the institution) and unexpected reasons (familiarity, poor navigation aids, reputation). The potential for improved accessibility would be accurate if all people were entitled to access those services.

The census includes respondent-reported data that is subject to interpretation. For example, variables like disability and health status are self-reported, and the question is unspecific.

Respondents may not find a suitable response option. For example, ethnicity has no category for Caucasian or mestizo populations representing a substantial part of the population. People with mixed backgrounds may find no suitable option to represent them.

The census is still well suited for this study: the data has been digitized, and sociodemographic data are linked with the residential block. The place of residence is a common starting point for people undergoing hemodialysis or radiotherapy, children, the elderly, and those not engaged in formal employment.

Mobile phone data is impractical because it cannot be accurately tied to reliable sociodemographic data; coverage varies among the population and excludes those unregistered as users or without a phone. It also has technical limitations.¹⁰¹

Accessibility and spatial equity have been studied in Cali by the Research Group on Transport, Transit and Roads (GITTV) of the Faculty of Engineering of the Universidad del Valle. Members of this group contributed to the validation of the AMORE Platform, and the preliminary findings of the AMORE Platform are consistent with those of the GITTV and other authors.^{102–107}

Harms, risks, and ethical considerations

This observational study addresses the impact of mobility on health equity without researching human subjects and by integrating anonymized coded secondary data obtained from openly available records.

The study does not involve human subjects' research. The AMORE Platform and dynamic geospatial analyses expose social justice issues and potential solutions of benefit to society by enabling informed decisions relevant to policies, plans, and procedures for improving health equity. This data can also predict or monitor changes in urban accessibility. The data used is anonymized and publicly available. Under Colombian law, this component fits the definition of research without risk, as described in Resolution 008430-1993 of the Ministry of Health.¹⁰⁸ This was corroborated on 25th July 2022, by the Research Ethics Committee of the School of Engineering of the Universidad del Valle, which declared the project "without risk" per Colombian law (Ref: CEIFI 010-2022). The project was cleared on September 16, 2022 by the Commission on Ethics in Animal and Human Experimentation (CEEAH), and the Vice-Rector for Research, Universitat Autònoma de Barcelona (Ref: CEEAH-6100) on September 20, 2022.

The study can challenge current thinking with data and disrupt traditional approaches to land use and health services planning that may perpetuate pervasive inequalities that could fuel social strife and corruption.^{102–105,109–115}

The ethical approach of this study follows the broader principles and considerations of public health ethics and health systems ethics; it generates population data valuable to address inequity and social injustice, is helpful for accountability and is relevant to intersectoral action.^{116,117} The need for further guidance on these issues remains a challenge for cross-sectoral collaboration. It is part of the ongoing discussions on stakeholder engagement in global health.^{73,117}

Accessibility is a determinant of health on the supply side of health equity.¹¹⁹ Useful, valid equity assessments in accessibility matter to health systems and social justice. Having action-oriented data to challenge established thinking might contribute to various SDGs, such as improving good health and well-being (SDG 3), reducing inequalities (SDG10), having sustainable cities and communities (SDG11), improving infrastructure (SDG 9), and facilitating partnerships to achieve the SDGs (SDG17).^{3,48,52,60,116}

These ideals are synergic with other urban development and planning initiatives on a human scale: Smart City, the 15-minute City, the Caring City, and the Committed City. Having data is the first step for technology to serve the needs of urban dwellers and inform public policy regularly or when facing health emergencies and pervasive inequities.^{52,120–122}

The risks of this study are especially those associated with data science and artificial intelligence. Travel time data providers do not disclose the algorithms they use. These are empirically known to be accurate and are expected to be more accurate for the areas most travelled by people with network-engaged smartphones and sites where infrastructure and conditions remain stable; accuracy may vary across the city.^{27,123,124}

There is a risk of errors in programming or labelling data; to control this risk, the validity of the data was tested, repeatedly reviewed, and found sensible by experts and local contributors. The chance that inaccuracies result from clustering traffic and times is low and is unlikely to change the overall picture the project analyzes.

The project reveals accessibility levels for populations and sectors of the city. It uses heuristic analysis to identify areas in which new services would significantly impact accessibility. These areas, like traffic conditions, may evolve. However, the data provided to inform decisions gives an overall idea of the locations that would optimize accessibility. It is unlikely that conditions and populations would change fast enough to make those broad estimations suddenly irrelevant. Regular updating of the AMORE Platform would allow for assessing these variations and would be the subject of further studies after this test case. Additional factors influence the use of a service, including insurance coverage entitlements. Exploring this would require different data layers and funding that exceeds the purpose and scope of the test case and would be a matter of subsequent implementation. There is an inherent risk of revealing social injustices or inequities that can lead to discomfort, alienation, or corrective action.

Dissemination, promotion, and implementation of findings

As part of the project, communication tools such as [animations](#), [infographics](#), videos, summaries, and logos were developed.

The research team seeks to publish its reports in open-access impactful journals and present them to diverse audiences, including observatories, networks, and intersectoral groups.

The planned reports include:

- Accessibility of health services for the urban population of Cali, 2020: urgent care and frequent care
- Predicted accessibility of health services for the urban population of Cali with the addition of health services in areas that would maximize accessibility (urgent care and frequent care scenarios) or changes in service schedules (frequent care)
- Editorials and methodological articles.

Protocol study status

Data extraction for research reports was initiated in January 2022 and is underway.

Data availability

Source data

The Data Sources section provides a list of publicly available data sources that will be used in this project. Relevant interfaces for each case study will be published with research results at <https://www.iqartil.net/proyectoAMORE/>.

Extended data

Figshare: Theory of Change for AMORE Project Protocol 2022 <https://doi.org/10.6084/m9.figshare.20485404.v2>.⁶⁹

This project contains the following extended data:

- The 2022 goals of the AMORE project and how they will be achieved

Open Science Framework: Dynamic geographical accessibility assessments to improve health equity: protocol for a test case in Cali, Colombia. <https://doi.org/10.17605/OSF.IO/ETPMA>.⁷⁰

This project contains the following extended data:

- 20220726 Protocol 5.5 AMORE Project_Aproved CEII-UdeIV Assembled.pdf
- 20220726 Protocol 5.6.1 AMORE Project_Aproved CEIIFI - CEEAH.pdf

Data are available under the terms of the [Creative Commons Attribution 4.0 International license](#) (CC-BY 4.0).

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Luiz Galvao

Oswaldo Cruz Foundation, Rio de Janeiro, Brazil

The paper proposes a new approach to assessing the accessibility of health services in urban areas. The approach uses dynamic travel times, which take into account traffic congestion, to assess the ease with which people can reach health services from their homes. The paper also takes an equity perspective, assessing how the accessibility of health services varies for different populations. It argues that the traditional approach to assessing accessibility, which uses static metrics such as distance or average travel time, is no longer adequate in the context of urban sprawl and traffic congestion. Dynamic travel times provide a more accurate measure of accessibility, as they take into account the real-world conditions that people face when trying to reach health services.

The paper uses data from Cali, Colombia, to show that people in vulnerable populations, such as those living in poverty or those with disabilities, often have less access to health services than people in more privileged populations.

The conclusions includes a new framework for assessing dynamic accessibility to health services. The framework takes into account the following factors:

- The location of health services
- The location of people's homes
- Traffic congestion
- The sociodemographic characteristics of the population

The paper argues that the framework can be used to identify areas where accessibility to health services is poor, and to target interventions to improve accessibility.

Overall, the paper is a valuable contribution to the literature on accessibility to health services. The new framework proposed by the authors has the potential to improve the way that accessibility to health services is assessed and improved.

Is the rationale for, and objectives of, the study clearly described?

Yes

Is the study design appropriate for the research question?

Yes

Are sufficient details of the methods provided to allow replication by others?

Yes

Are the datasets clearly presented in a useable and accessible format?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: environmental and global health

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 30 March 2023

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Airton Tetelbom Stein 

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This protocol proposes an approach to assessing the place of residence as a spatial determinant of health in cities where traffic congestion might impact health services accessibility. The study provides dynamic travel times presenting data in ways that help shape decisions and spur action by diverse stakeholders and sectors.

This is a very adequate protocol to discuss a valid equity assessment in accessibility to health system and social justice.

In the Introduction section, it could have a broader view and suggest to include this article for rationale - Hosking J, Braubach M, Buss D, Khayesi M, Filho VP, de Sá TH. [Towards a global framework for transport, health and health equity](#). Environ Int. 2022 Nov;169:107472. doi: 10.1016/j.envint.2022.107472. Epub 2022 Aug 17. PMID: 36116365.

There is a need to include in the introduction an article discussing the PROGRESS-Plus strategy, such as: O'Neill J, Tabish H, Welch V, Petticrew M, Pottie K, Clarke M, Evans T, Pardo Pardo J, Waters E, White H, Tugwell P. [Applying an equity lens to interventions: using PROGRESS ensures consideration of socially stratifying factors to illuminate inequities in health](#). *J Clin Epidemiol*. 2014 Jan;67(1):56-64. doi: 10.1016/j.jclinepi.2013.08.005. Epub 2013 Nov 1. PMID: 24189091.

There is a need to discuss this report - "*Integrating health in urban and territorial planning: A sourcebook for urban leaders, health and planning professionals*" - <https://unhabitat.org/integrating-health-in-urban-and-territorial-planning-a-sourcebook-for-urban-leaders-health-and>, in which it describes the need to build habitable cities on a habitable planet: Processes to guide the development of human settlements – in this document referred to as “urban and territorial planning (UTP)”; and concern for human health, well-being and health equity at all levels – from local to global, and from human to planetary health. As there is a need for a closer relationships between public health and spatial planning.

Population ageing is one of the main demographic phenomena in Latin America and the Caribbean and in the world. This topic should also be addressed in this protocol, as this population has several disabilities due to chronic illness and inequity is something to manage based on this demographic transition.

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Is the rationale for, and objectives of, the study clearly described?

Yes

Is the study design appropriate for the research question?

Yes

Are sufficient details of the methods provided to allow replication by others?

Yes

Are the datasets clearly presented in a useable and accessible format?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: I am a family physician and epidemiologist. My main interest in research is health service research, primary health care and clinical guidelines.

We confirm that we have read this submission and believe that we have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

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2.2 Glossary and abbreviations

- **Accessibility:** “a fundamental concept in transport geography and urban planning. It refers to individuals’ ability to travel and participate in activities given the available transport and land use system (Pirie 1979, Pooler 1987)”.³⁹ In this study, geographic accessibility refers to a characteristic that depends on the origin of a journey (the population-weighted centroid of the traffic analysis zone where a resident dwells), the location of the service with the shortest travel time from that origin, and the predicted journey time.⁴⁰ It can be described as the possibility for health service users to effectively reach these services, providing a performance measurement of the urban and transport systems. Accessibility is therefore linked to land use and transportation.^{4,41,42} Four components are often considered when assessing accessibility to opportunities such as health services: land use, transport, temporal, and the individual.^{42,43} Accessibility, for some, captures the possibility of individuals to participate in activities, such as reaching a health service.³⁴
- **Accessibility indicators:** These indicators describe the ease of access to opportunities, such as health services. There are numerous and evolving categories of accessibility indicators, and for this study, we focus on how transport systems enable people to reach desired services or locations. Specifically, we focus on travel times and populations that, by utilizing a transport system, will likely reach a (health-related) service within a specified travel time threshold, given a certain level of traffic congestion.^{43–45} This study’s proposed approach addresses several limitations identified in analyses of accessibility definitions that focused on policy and purposeful travel to tracer chronic care and acute care services, which were raised at the outset of this project.⁴⁵ In this study, most indicators are expressed as absolute population or percentage of the population. These indicators are disaggregated by the sociodemographic characteristics of the population, housing characteristics, and location.⁶ An analysis has highlighted the need for indicators for standalone services, accounting for specific contexts, policy needs, and the availability of geographic information systems that provide accurate travel-time measurements and predictions.^{3,4,45}

- **Acute care:** a global burden of disease assessment proposes that “acute care involves conditions that have a short, relatively severe course, and potentially curable or reversible”.²²⁵ Examples pertinent to this work are the so called “first hour quintet” conditions: cardiac events, acute coronary syndromes, strokes, respiratory failures, and severe trauma.¹¹³ Also, other conditions such as epileptic status, abrupt mental changes, major bleeding or severe adverse events such as a serious allergy, sepsis, or treatment complication.^{113,410,411}
- **AMORE**, the project's and platform's name, is the Spanish acronym for **Análisis espacial con Macrodatos para Orientar los Resultados en pro de la Equidad en salud**, or “spatial analysis with big data to guide health equity outcomes.” This name also honours the doctoral student's family. The project engaged current and former policymakers across various sectors, interest holders, and knowledge users (e.g., civil servants, government officials, service providers, service-user advocates, and non-governmental organisations), as well as academics, science communicators, and data scientists. These contributors influenced the conceptualisation, implementation, reporting, and knowledge use. They helped design a web-based, interactive platform that integrated open and big data to measure and predict accessibility to tracer services, applying research recommendations to support participatory policy shaping.^{6,7,9,61,342}
- **Chronic care:** a global burden of disease assessment proposes that “Chronic care focuses on the management and long-term treatment of medical conditions that are persistent, progressive despite treatment, and typically incurable”.²²⁵
- **Congestion, traffic:** The US Department of Transportation has been defined traffic congestion as an “*excess of vehicles on a portion of roadway at a particular time resulting in speeds that are slower -sometimes much slower - than normal or “free flow” speeds. Congestion often means stopped or stop-and-go traffic.*”⁴¹² An OECD report states “Congestion is a situation in which demand for road space exceeds supply.”⁴¹³

- **Cumulative opportunities accessibility (also called *cumulative accessibility opportunities*):** This metric represents the number of residents estimated to reach any studied services at a given time, travelling by car from their residence to the service location with the shortest travel time. It applies an arbitrary travel time threshold, represented as an isochrone in the AMORE Platform's cartography. It does not account for whether an individual can access one or multiple services within that threshold.^{6,178,179,412,414} This is a dynamic concept, as accessibility changes throughout the day.⁴
- **Cumulative opportunity measures** (see cumulative opportunities accessibility: see above.
- **Dynamic spatial-temporal accessibility measurements (DSTAM):** place-based measurements applied in our accessibility assessments to service (opportunity) offering the shortest travel time given traffic congestion and other network characteristics.⁴¹⁵
- **Dynamic cumulative accessibility:** refers to the population covered by the isochrone for a travel-time threshold at a given moment.
- **Equity, and Health Equity:** according to the World Health Organization, "Equity is the absence of unfair, avoidable or remediable differences among groups of people, whether those groups are defined socially, economically, demographically, or geographically or by other dimensions of inequality (e.g. sex, gender, ethnicity, disability, or sexual orientation). Health is a fundamental human right. Health equity is achieved when everyone can attain their full potential for health and well-being. Health and health equity are determined by the conditions in which people are born, grow, live, work, play and age, as well as biological determinants. Structural determinants (political, legal, and economic) with social norms and institutional processes shape the distribution of power and resources determined by the conditions in which people are born, grow, live, work, play and age."^{322,416}
- **Global Navigation Satellite Systems, Precise Navigation Satellite Systems, and Positioning Navigation and Timing systems** are interchangeable terms that refer to satellite networks synchronised to

pinpoint locations. These systems can collect travel time data and establish journey times based on characteristics and information from those traversing parts of a journey. These systems seamlessly provide timing and positioning to many transportation systems and billions of smartphone users.⁴¹⁷

- **Governance:** The Pan American Health Organization’s Policy on Research for Health CD49/10 adopted a governance definition describing it as the processes for collective action that structure the interaction between actors, process dynamics, and the formal and informal rules with which society determines its behaviours, makes decisions, and applies them.^{180,418} WHO’s Strategy for Urban Health defines governance as the framework through which decisions affecting the health of urban dwellers are made, delivered, and accounted for.⁴⁹
- **Health Equity:** Health equity occurs when everybody can achieve the fundamental right to health because unfair, avoidable, or remediable differences among groups of people are absent, whether those groups are defined socially, economically, demographically, geographically, or by other dimensions of inequality.^{195,419} Health equity is integral to urban governance.⁴²⁰
- **Implementation research:** “systematic approach to understanding and addressing barriers to effective and quality implementation of health interventions, strategies and policies. IR is demand-driven and the research questions are framed based on needs identified together with relevant stakeholders/ implementers in the health system”¹¹
- **Interest-holders** refer to groups of people with a legitimate interest in the issue, economic, social, environmental, or, particularly in this case, equitable health services accessibility. This concept has recently emerged to replace “stakeholder,” which reminds people of power relations in territorial claims instead of the intended collaborative or shared nature of contributions towards advancing rights and impact.⁴²¹
- **Knowledge (action) networks:** “social relationships and the networks these relationships constitute are influential in explaining the processes of knowledge creation, diffusion, absorption, and use”.¹

- **Knowledge users** frequently refer to those using knowledge to shape change through decisions and actions. These could be policymakers, managers, patient advocates, or communities, and in this study, those directly or indirectly shaping urban and health services planning agendas.^{10,22,422,423}
- **Optimising urban accessibility** refers to implementing land adjustments that maximise the population's ability to reach a type of health service within a set travel time threshold and means.⁴⁰⁷
- **People-centred healthcare:** "An approach to care that consciously adopts individuals', carers', families', and communities' perspectives as participants in, and beneficiaries of, trusted health systems that are organised around the comprehensive needs of people rather than individual disease, and respects social preferences. ... People-centred care is broader than patient and person centred care, encompassing not only clinical encounters, but also including attention to the health of people in their communities and their crucial role in shaping health policy and health services".²⁴ The World Health Assembly's Framework on integrated people-centred health services calls for people-centred health services, and the framework is being promoted.^{23,25–28}
- **Spatiotemporal Accessibility Assessment:** Evaluates accessibility by integrating both spatial and temporal dimensions, providing a comprehensive view of how access changes over time and space. (See Dynamic spatial-temporal accessibility, Temporal Accessibility Analysis, Time-Dependent Accessibility)^{19–21 9,11–13,15,190,238}
- **Stakeholder:** a term that originates from colonial and land-claiming language as it refers to staking a claim, which can be problematic in contexts involving Indigenous peoples, land rights, or post-colonial societies. It can be vague or misunderstood, especially outside business or policy circles. In policy circles, it is frequently used as a synonym for an interest-holder, although there is a growing trend to use the latter term, which focuses on rights and impact instead of power or influence. Terminology evolved as this work progressed. This report will use the proposed term "interest holder", described above.⁴²¹

- **Research reporting standards:** guidelines adopted by publishers, knowledge brokers and producers to enhance the value and quality of research.^{424,425}
- **Social Justice:** “The objective of creating a fair and equal society in which each individual matters, their rights are recognized and protected, and decisions are made in ways that are fair and honest.”^{173,426}
- **Temporal Accessibility Analysis:** Focuses on how accessibility varies across different periods, accounting for service availability and demand fluctuations. (See: Time-Dependent Accessibility, Spatiotemporal Accessibility)⁴³
- **Time-Dependent Accessibility Assessment:** Analyses accessibility considering the temporal dynamics of transportation networks and service operations.⁴³

2.3 Publications

Cuervo LG, Villamizar CJ, Cuervo D, Zapata P, Ospina MB, Valencia SM, Polo A, Suárez A, Bula MO, Miranda J, Millán G, Cuervo DE, Owens NJ, Piquero F, Hatcher-Roberts J, Paredes GD, Navarro MF, Minotta IL, PaltaC, Martínez-Herrera E, Jaramillo C, on behalf of the AMORE Project Collaboration. “**Improving Accessibility to Radiotherapy Services in Cali, Colombia: Cross-sectional Equity Analyses Using Open Data and Big Data Travel Times from 2020.**” International Journal for Equity in Health. 23, 161 (2024). <https://doi.org/10.1186/s12939-024-02211-6> Video Abstract: <https://youtu.be/8lC1JqywAwk> Int. J. Equity Health [2023] Q1 JCR/Scimago; IF: 4.5/4.3; JCI 1.2; P 90 H:82

Villamizar-Jaimes CJ, Cuervo LG, Martínez-Herrera E, Cash-Gibson L, Jaramillo Molina C, Benach J. A **Stakeholder Assessment of an Innovative Platform to Improve Spatial Accessibility to Healthcare Services in Cali, Colombia.** Rev Panam Salud Publica. 2024;48:e69. <https://doi.org/10.26633/RPSP.2024.69>. Available at: <https://journal.paho.org/en/articles/improving-spatial-accessibility-health-care-services-cali-colombia-stakeholder-assessment> Rev. Panam. Salud Publica [2023] Q3 JCR/Scimago IF:2.0/.2.0; JCI 0.5; P 46.8 H:67

Cuervo LG, Villamizar CJ, Osorio L, Ospina MB, Cuervo DE, Cuervo D, Bula MO, Zapata P, Owens NJ, Hatcher-Roberts J, Martin EA, Piquero F, Pinilla LF, Martínez-Herrera E, Jaramillo C, on behalf of the AMORE Project Collaboration. **“Dynamic Measurements of Geographical Accessibility Considering Traffic Congestion Using Open Data: A Cross-Sectional Assessment for Haemodialysis Services in Cali, Colombia.”** *The Lancet Regional Health - Americas* 34 (June 1, 2024): 100752. <https://doi.org/10.1016/j.lana.2024.100752>. **Lancet Regional Health-Americas** [2023] **Q1 JCR/Scimago**; **IF**: 7.0/6.8; **JCI** 2.93; **P98 H**: 27

Cuervo LG, Martínez-Herrera E, Osorio L, Hatcher-Roberts J, Cuervo D, Bula MO, Pinilla LF, Piquero F, and Jaramillo C. **“Dynamic Accessibility by Car to Tertiary Care Emergency Services in Cali, Colombia, in 2020: Cross-Sectional Equity Analyses Using Travel-Time Big Data from a Google API.”** *BMJ Open* 12, no. 9 (September 1, 2022): e062178. <https://doi.org/10.1136/bmjopen-2022-062178>. **BMJ Open** [2022] **Q1 JCR y Scimago IF**: 2.9/2.8 ; **JCI** 0.72; **P** 75.99 **H**: 160

Cuervo, LG, Jaramillo C, Cuervo D, Martínez-Herrera E, Hatcher-Roberts J, Pinilla LF, Bula MO, Osorio L, Zapata P, Piquero Villegas F, Ospina MB, and Villamizar CJ. **“Dynamic Geographical Accessibility Assessments to Improve Health Equity: Protocol for a Test Case in Cali, Colombia.”** *F1000Research*, November 28, 2022. <https://doi.org/10.12688/f1000research.127294.1>. *F1000Research* [2022] **Q1 Scimago IF**: H: 105

2.4 Preprints

Brown J, Dewidar O, Chamberlain C, Cuervo LG, Ellingwood HN, Faber S, et al. **Evaluating the outcome and impact of an integrated knowledge translation approach in the development of an equity reporting guideline: a cross-sectional survey.** Aug 2025. <https://doi.org/10.1101/2025.08.26.25334422>

Cuervo, LG, Bula MO, Cuervo D, Echeverri DH, Rocha TAH, Jaramillo C, Martínez Herrera E, Miranda JJ, Ospina MB, Tejerina L, Valencia SM, Vivas H. **“Enhancing Health Services Accessibility in Congested Urban Areas with an Equity Focus: A Case Study in Cali Leveraging People-Centered Approaches and Open Data to**

Support Public Policy and Engagement.” SSRN Scholarly Paper. Rochester, NY: Social Science Research Network, January 29, 2025.
<https://doi.org/10.2139/ssrn.5117085>.

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<https://doi.org/10.2139/ssrn.4722439>.

Cuervo LG, Villamizar CJ, Osorio L, Ospina MB, Cuervo DE, Cuervo D, Bula MO, Zapata P, Owens NJ, Hatcher-Roberts J, Martin EA, Piquero F, Pinilla LF, Martinez-Herrera E, Jaramillo C. **“Cross-Sectional Equity Analysis of Accessibility by Automobile to Haemodialysis Services in Cali, Colombia, in 2020”.** (December 9, 2022). Available at SSRN: <https://ssrn.com/abstract=4299562>

Cuervo LG, Cuervo D, Hatcher-Roberts J, Martínez Herrera E, Pinilla LF, Piquero F, Ospina M, and Jaramillo Molina C. **“AMORE Project: Integrated Knowledge Translation and Geospatial Analysis to Improve Travel Times to Health Services (Accessibility) and Health Equity in Cali, Colombia: A Proof of Concept Using Mixed-Methods Research.”** Preprint. Thesis Commons, November 19, 2021.
<https://doi.org/10.31237/osf.io/4atqc>.

2.5 Editorials

Cuervo LG, Martínez-Herrera E, Cuervo D, and Jaramillo C. **“Improving equity using dynamic geographic accessibility data for urban health services planning.”** (E-Publication ahead of print) 11 Jun 2022. Gaceta Sanitaria 36, no. 6 (November 1, 2022): 497–99. <https://doi.org/10.1016/j.gaceta.2022.05.001> **Gac. Sanit.** [2022] **Q1 JCR** y **Scimago IF:** 1.9/1.8 ; **JCI** 0.63; **P** 26.4

2.6 Ethics approvals

- Comité de Ética en Investigación, Vicedecanatura de Investigaciones, Facultad de Ingeniería, Universidad del Valle. Acta de Aval No. 010-2022 del 25 de julio de 2022.
- Vicerectorat d'Investició, Comisión de Ética en la Experimentación Animal y Humana (CEEAH), Universitat Autònoma de Barcelona. Proyecto CEEAH 6100

Evaluado favorablemente el 16 de septiembre de 2022, comunicado el 5 de octubre de 2022.

2.7 Events

Cuervo, Luis Gabriel; Martínez Herrera, Eliana. **Jornada Línea de Investigación LIESU GEPI: Salud urbana a diez años de su creación.** Presentations and debate by PhD students addressing urban health, at the National Faculty of Public Health. 28 August 2025. Universidad de Antioquia. Presentation: "Equitable Access to Health Services Cali, Colombia (AMORE Project)" Recording: <https://youtu.be/44mcRs5S6f0>

Jaramillo, Ciro; Cuervo, Luis Gabriel; Rocha, Thiago. Hosted by ProPacífico; City Cancer Challenge **WORKSHOP: Integration Plan for Data Exchange in Breast Cancer Management for the (Pacific) Region.**; Cali, Valle del Cauca, Colombia, April 25, 2025.

Valencia Cadavid, S.M. **IA en Salud: de la Promesa a la Adopción en el sistema de salud.** Medellín, Colombia, 2025-05-28. Available from:

<https://www.youtube.com/live/aYsONOtUiRk?si=q2beptTCe2WA1f0i&t=1228>

Cuervo, Luis Gabriel. **Consortium for Sustainable Urbanization – Green Cities Lecture: Cali, Colombia.** 5 Feb. 2025. <https://csu.global/events/green-cities-cali-colombia/> Recording: <https://youtu.be/zh3KMHgpMvo?si=142DFkWkJFD-nQqA>

Jaramillo, Ciro. **“Accesibilidad espacial a la infraestructura crítica en situaciones de emergencia.”** Presented at the Primera Reunión Interregional sobre el Fortalecimiento de Capacidades de Preparación ante Emergencias en Salud y Desastres en Ciudades y Entornos Urbanos - OPS/OMS, Quito, Ecuador, October 16, 2024. <https://www.paho.org/es/eventos/primera-reunion-interregional-sobre-fortalecimiento-capacidades-preparacion-ante>.

Cuervo, Luis Gabriel. **“Digitalización, en 2º Seminario-Taller Internacional – Respetando la Salud Planetaria: hacia un enfoque transdisciplinario, sistémico, y político.”** Medellín, agosto 28-30 de 2024.

2022-2024. **Foros virtuales de la Línea de Investigación en Epidemiología y Salud Urbana – LIESU.** Presentaciones anuales a cargo de Luis Gabriel Cuervo, en representación del Proyecto AMORE. Moderadora Eliana Martínez Herrera, Facultad Nacional de Salud Pública, Universidad de Antioquia. Medellín, Colombia.

2023 III Simposio Gestión de Datos: Ciudades Inteligentes. Molina C. **Medición de accesibilidad espacial a servicios prioritarios de salud, una perspectiva de equidad territorial partiendo de datos públicamente disponibles.**

https://padlet.com/Proyecto_AMORE_Project/proyecto-amore-project-ocq9d91xtsew203j/wish/wKmOZ5dyq9DoQzMA

2023 WHO LEAD Innovation Challenge - World Health Organization. **Finalists: Driving Towards Equity: the AMORE Project.**

<https://youtu.be/rNgFYmJNp24?si=O3gAzPPnXLD2Wvvv&t=3741> /

[https://padlet.com/Proyecto_AMORE_Project/proyecto-amore-project-ocq9d91xtsew203j/wish/jpoxaj0KjyN0ZbPE /](https://padlet.com/Proyecto_AMORE_Project/proyecto-amore-project-ocq9d91xtsew203j/wish/jpoxaj0KjyN0ZbPE/)

https://padlet.com/Proyecto_AMORE_Project/proyecto-amore-project-ocq9d91xtsew203j/wish/dMA1W86lAXRkQ4OV

Jaramillo C, III Simposio de Gestión de datos: ciudades inteligentes. [**Data management: smart cities**] <https://www.escuelaing.edu.co/es/eventos/iii-simposio-gestion-de-datos-ciudades-inteligentes/#perfiles-de-los-conferencistas>

International Forum on Quality and Safety in Healthcare 2023, Copenhagen. L1: **A dynamic, interactive platform for assessing urban health services accessibility and equity.** Luis Gabriel Cuervo, representing the AMORE Project Collaboration. https://internationalforum.bmj.com/copenhagen/wp-content/uploads/sites/18/2023/05/L2-additional-20230516-AMORE_Project_IFQSH_Notes-Luis-Gabriel-Cuervo.pdf

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III Simposio Internacional de Doctorandos en Desarrollo Urbano Sustentable de Latinoamérica y el Caribe – 2023. **Área 03 Accesibilidad y Movilidad.** <https://redeus.org/luis-gabriel-cuervo/> and <https://redeus.org/iii-simposio-internacional-de-doctorandos-en-desarrollo-urbano-sustentable-de-latinoamerica-y-el-caribe/>

PRB -Webinar: **Big data analysis on a Shoestring. Using publicly available data for population and global health research.** March 13, 2023. Population Reference Bureau. Website: <https://www.prb.org/articles/analyzing-big-data-on-a-shoestring-budget/>

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Cuervo, Luis Gabriel. “Hybrid Oral Session on Comprehensive Primary Care in Promoting Sustainability: **Assuring Access to Health Care for All: A New Approach to Assess Equity in Accessibility to Health Services.**” Hybrid Oral Session on Comprehensive Primary Care in Promoting Sustainability: presented at the Seventh. Global Symposium on Health Systems Research., Ágora Conference Center, Bogotá DC., November 2, 2022. <https://youtu.be/A2Ji47cM6wA?t=810>.

Martínez-Herrera E, Cuervo LG, Villamizar CJ, Cuervo D, and Jaramillo C. “**Equitable Accessibility to Health Services Using Timely Measurements.**” In *International Society for Urban Health*. Sevilla, Spain: International Society for Urban Health., 2022. <https://doi.org/10.6084/m9.figshare.21375750.v1>.

Cuervo LG, Jaramillo C. UKRI-GCRF **Gridding Equitable Urban Futures in Areas of Transition GREAT—Presentation of Proyecto AMORE.** July 26, 2022. The presentation was made to the consortia formed by the University of Lancaster and the Bartlett/Development Planning Unit, UCL, the Universidad del Valle in Colombia, and the Technological University of Havana in Cuba.

Jaramillo Molina, Ciro, Lyda Osorio, Luis Gabriel Cuervo, and Carmen Juliana Villamizar. “**Mejorando la equidad en la accesibilidad (tiempos de viaje) a los servicios de salud.**” XXIV Simposio Nacional e Internacional de Investigaciones en Salud; consecuencias de la pandemia: una mirada global. (26m 27s). Cali, Colombia, Oct 21, 2022. <https://salud.univalle.edu.co/noticias/xxiv-simposio-de->

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<https://youtu.be/ijlEh0zlObo?t=4994>

Speaker: Luis Gabriel Cuervo; Chair: Natalia Villamizar Duarte; Commentator: Kate Lowe, University of Illinois at Chicago. Panel 2, September 9, 2022. **Simple metrics and timely measurements to advance equitable accessibility to health services.** Recordings to be added to <https://intalinc-lac.com/eventos/> Temporary access <https://drive.google.com/file/d/12LMS8eEgKQA82tnvA0GH6kUoWJI7ejzR/view>

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1. Qian, H.; Sun, Z.; Zhang, Y.; Zhang, T.; Chen, Y. **Incorporating Travel Purposes into the Dynamic Accessibility Evaluation for Elderly Public Transport Based**

- on End-to-End Travel.** *Journal of Transport Geography* 2026, 130, 104457, doi:[10.1016/j.jtrangeo.2025.104457](https://doi.org/10.1016/j.jtrangeo.2025.104457).
2. Sánchez-Grajales, J.-D. 1; Bucheli, V. 1; Jaramillo, C. 1 1 U. del V. **Data Analytics Model of the Accessibility-Vulnerability Relationship: Risk Scenarios in Urban Areas.** *Rev. Fac. Ing.* 2025, 34(73) 1–16, doi:[10.19053/01211129.v34.n73.2025.18085](https://doi.org/10.19053/01211129.v34.n73.2025.18085).
 3. Orellana, F.P.; Díaz, M.F.; Vargas, D.N.; Gajardo, F.S. **Evaluación de la accesibilidad espacial a servicios de Diálisis en el Servicio de Salud Metropolitano Sur Oriente.** *Revista Chilena de Salud Pública* 2025, 29, e75004–e75004, doi:[10.5354/0719-5281.2025.75004](https://doi.org/10.5354/0719-5281.2025.75004).
 4. Lubbers, R.; Weitkamp, G.; Hierink, F.; Ray, N.; Oporia, F.; Businge, O.; Biesma, R. **Geospatial Modelling Reveals Flood-Driven Inequities in Nutrition-Sensitive Healthcare Access across Kampala, Uganda.** 2025. *Research Square*. <https://doi.org/10.21203/rs.3.rs-8055572/v1>
 5. Cazacu, C.; Dumitrache, L.; Mareci, A.; Cioclu, A.; Petre, A.-A.; Cazacu, C.; Dumitrache, L.; Mareci, A.; Cioclu, A.; Petre, A.-A. **Geospatial Analysis of Emergency Healthcare Accessibility: Bridging Urban–Rural Disparities in Romania.** *Land* 2025, 14, doi:[10.3390/land14122321](https://doi.org/10.3390/land14122321).
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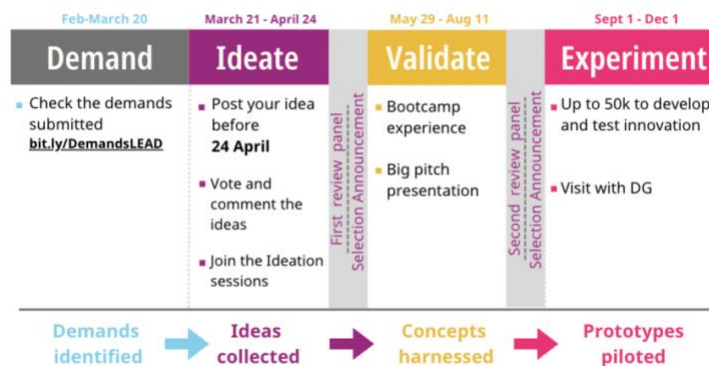
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2.9 World Health Organization's 2023 LEAD Innovation Challenge schedule



Calendar of the LEAD Innovation Challenge program 2023

Phase	Date	Activity
Demand Phase	Feb 8	Demand Discovery Training of Trainers
	Feb 21	LEAD 2023 Launch. Demand phase and portal opens for demand submissions.
	Feb 21 + 23	Lean-In webinar – Demand approach. First session as speaker for launch. Second session as expert for first discovery workshop
	Feb 23, 28, Mar 9, 14	Demand discovery workshops. In coordination with RO's and CO's.
Demand and Ideate	Mar 21	Matchmaking Event. Open Innovation style event to discuss demands and seek solutions. Ideation portal opens.
Ideate Phase	Mar 21 + 23	Lean-In 'webinar' - Ideation First session as part of the hackathon Second session as expert for first ideation workshop
	Mar 23, 28, Apr 4, 13, 18	Ideation Workshops. In collaboration with RO's and CO's.
	Apr 24	Last day to submit ideas.
	May 1-5	Panel review of ideas.
	May 11	Panel meets to select ideas for validate phase.
	May 23	Validate phase selections announced.
Validate Phase	Jun 5-16	Accelerator bootcamps (2 in succession).
	Jul 11-13	Practice pitches
	Aug 8 + 9	The Big Pitch
	Aug 17	Experiment selections announced
	Sep 1	Experiment phase kickoff



2.10 Data Repositories for Urban Accessibility Analysis: Open Access Census and Health Services²⁶²

Countries with Open Access Digital Census Providing Disaggregated
Sociodemographic Data, by WHO Region

AFRO (Africa)

- **Ghana** – Ghana Statistical Service: <https://statsghana.gov.gh/>
- **Kenya** – Kenya National Bureau of Statistics: <https://www.knbs.or.ke/?p=5732>
- **South Africa** – Statistics South Africa: https://www.statssa.gov.za/?page_id=3839

AMRO (Americas)

- **Argentina** – National Institute of Statistics and Censuses (INDEC):
<https://www.indec.gob.ar/indec/web/Nivel4-Tema-2-41-135>
- **Brazil** – Brazilian Institute of Geography and Statistics (IBGE):
<https://www.ibge.gov.br/en/statistics/social/population.html>
- **Canada** – GeoBase / Statistics Canada:
<https://www150.statcan.gc.ca/n1/en/type/data>
- **Colombia** – National Administrative Department of Statistics (DANE):
<https://www.dane.gov.co/index.php/en/statistics-by-topic-1/population-and-demography/national-population-and-housing-census-2018>
- **Mexico** – National Institute of Statistics and Geography (INEGI):
<https://www.inegi.org.mx/programas/ccpv/2020/>
- **Peru** – National Institute of Statistics and Informatics (INEI):
<https://www.inei.gob.pe/estadisticas/censos/>
- **United States** – U.S. Census Bureau: <https://www.census.gov/data.html>

EMRO (Eastern Mediterranean)

- **Egypt** – CAPMAS: <https://www.capmas.gov.eg/>
- **Jordan** – Department of Statistics: <http://dosweb.dos.gov.jo/>

EURO (Europe)

- **France** – National Institute of Statistics and Economic Studies (INSEE): <https://www.insee.fr/en/accueil>
- **Germany** – Destatis: https://www.destatis.de/EN/Home/_node.html
- **United Kingdom** – Office for National Statistics (ONS): <https://geoportal.statistics.gov.uk/>

SEARO (South-East Asia)

- **India** – Office of the Registrar General & Census Commissioner: <https://censusindia.gov.in/>
- **Indonesia** – Badan Pusat Statistik (BPS): <https://www.bps.go.id/>

WPRO (Western Pacific)

- **Philippines** – Philippine Statistics Authority (PSA): <https://psa.gov.ph/population-and-housing>
- **Vietnam** – General Statistics Office: <https://www.gso.gov.vn/en/>

Regional and Global Repositories

- **WorldPop** – High-resolution population data for over 135 LMICs.: <https://www.worldpop.org/>
- **IPUMS International** – Harmonized census microdata for over 94 countries.: <https://international.ipums.org/international/>
- **GeoSUR** – Geospatial data from Latin America and the Caribbean.: <http://www.geosur.info/>
- **GADM** – Global administrative boundary datasets.: <https://gadm.org/>
- **CEPALSTAT** – Centralized statistical data platform from ECLAC.: <https://statistics.cepal.org/portal/cepalstat/index.html?lang=en>

- **Free GIS Data Repository** – Over 500 GIS data sources including population and boundaries.: <https://freegisdata.rtwilson.com/>

Countries with Open Access to Digitised and Georeferenced Health Services Information (By WHO Region)

AFRO (Africa)

- **Ghana** – Ghana Statistical Service: <https://statsghana.gov.gh/>
- **Kenya** – Kenya National Bureau of Statistics: <https://www.knbs.or.ke/?p=5732>
- **Nigeria** – HeRAMS Nigeria: <https://www.who.int/initiatives/herams/herams-nigeria>
- **Sierra Leone** – GRID3 Health Mapping: <https://grid3.org/>
- **South Africa** – Statistics South Africa: https://www.statssa.gov.za/?page_id=3839

AMRO (Americas)

- **Brazil** – Open Healthcare Access Map: <https://heigit.org/all-countries-of-central-and-south-america-now-on-open-healthcare-access-map/>
- **Colombia** – Open Healthcare Access Map: <https://heigit.org/all-countries-of-central-and-south-america-now-on-open-healthcare-access-map/> **REPS** – Registro Especial de Prestadores de Servicios de Salud: <https://prestadores.minsalud.gov.co/habilitacion/>
- **Mexico** – Open Healthcare Access Map: <https://heigit.org/all-countries-of-central-and-south-america-now-on-open-healthcare-access-map/>

EMRO (Eastern Mediterranean)

- **Egypt** – WHO GHFD Pilot: <https://ggim.un.org/2unwgic/documents/RAVI%20SHANKAR.pdf>
- **Jordan** – Department of Statistics: <http://dosweb.dos.gov.jo/>

EURO (Europe)

- **France** – Health Data Hub / INSEE: <https://www.insee.fr/en/statistiques>

- **Germany** – Destatis / GovData: <https://www.govdata.de/>
- **United Kingdom** – ONS Open Geography Portal: <https://geoportal.statistics.gov.uk/>

SEARO (South-East Asia)

- **India** – Data.gov.in Health Facilities: <https://data.gov.in/sector/health-family-welfare>
- **Indonesia** – Badan Pusat Statistik (BPS): <https://www.bps.go.id/>

WPRO (Western Pacific)

- **Philippines** – Philippine Statistics Authority (PSA): <https://psa.gov.ph/statistics/health-statistics>
- **Vietnam** – General Statistics Office: <https://www.gso.gov.vn/en/>

Regional and Global Repositories

- **Global Healthsites Mapping Project:** https://wiki.openstreetmap.org/wiki/Global_Healthsites_Mapping_Project
- **GRID3:** <https://grid3.org/>
- **Open Healthcare Access Map:** <https://heigit.org/all-countries-of-central-and-south-america-now-on-open-healthcare-access-map/>
- **WHO Geolocated Health Facilities Data (GHFD):** <https://www.who.int/data/GIS/GHFD>
- **WHO Global Health Facilities Database:** <https://www.who.int/news/item/10-03-2022-who-global-health-facilities-database-ensuring-access-to-primary-healthcare-and-uhc>

2.11 Ongoing activities and reports

The AMORE Project has been:

- Selected in a competitive process by the World Health Organization for a case study publication about its Urban Health Strategy.

- Chosen in a competitive process to deliver a book chapter to INTAL-InC LAC who will consider it for publication with Routledge/Taylor & Francis. “Making way for accessibility. Governance, plans, and policy for urban mobility, urban form, and social inclusion in Latin America and the Global South.”.
- Contacted to expand on its assessments in collaboration with various Universidad del Valle’s faculties.
- Considered for a policy brief on urban mobility and health to be developed by the Cali Mayor's Bureau.

2.12 Literature reviews (from the Zotero reference list)

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2.13 Student's applied professional and academic experience

- **Motivation and framing.** The project originated from a practical policy question in Cali: how traffic congestion affects timely access to time-critical services, and how evidence could guide equitable service planning.
- **Co-design.** Knowledge users and interest-holders were involved throughout, with iterative feedback cycles to refine inputs, outputs, and usability features.^{142,145,317,404}
- **Collaboration.** Multidisciplinary contributors clarified roles early to balance scientific integrity with practical constraints. Ethics and data-sharing were completed prior to analysis.
- **Reflections on platform development.** Iterative co-design ensured usability and transparency; documentation was maintained to support reproducibility.
- **Reflections on knowledge translation.** Briefings, infographics, dynamic images (e.g., GIFs), and other multimedia supported dialogue with diverse counterparts and knowledge users, and tested interpretability.
- **Knowledge translation.** Building on experience summarising and preparing evidence to inform policies and actions, and developing policies on research for health, nationally and internationally.^{31–33,167,427–435}
- **Challenges and mitigation.** Communicating uncertainty and findings demanded simplified visuals.
- **Lessons learned.** End-to-end engagement of knowledge users, interest holders, and data scientists. Target-oriented communication tools. Intuitive

and simple equity-focused metrics and graphics accessible to interest holders.

2.14 SDG Indicators Where Metrics of Accessibility and Traffic Congestion Intersect

Selected **UN-defined SDG indicators** most directly relevant to this thesis (based on the *UN SDG Global Indicator Framework* [UN Stats, 2023 update]):

- **SDG 3 (Good Health and Well-being)**
 - 3.8.1: Coverage of essential health services (including access to quality essential health-care services). For example, the proportion of the population able to reach a tracer service within a given time threshold, by any suitable means.
 - 3.8.2: Proportion of population with large household expenditures on health as a share of total household expenditure or income. For example, the proportion of the household's annual income that represents out-of-pocket expenditure for accessing health services.
- **SDG 9 (Industry, Innovation and Infrastructure)**
 - 9.1.1: Proportion of the rural population who live within 2 km of an all-season road (adaptable as a proxy for urban health facility access). For example, adding an indicator for urban areas, such as the proportion of the urban population who live within a 15-minute journey to a tertiary care emergency service by the most accessible means of transportation.
- **SDG 10 (Reduced Inequalities)**
 - 10.2.1: Proportion of the population living in low-income housing (or classified as low income), disaggregated by age, sex, and persons with disabilities, who face journeys equal to or greater than 20 minutes to tracer ambulatory care health services of frequent use.

- 10.2.1: Proportion of the population in low-income housing (or classified as low-income), disaggregated by age, sex, and persons with disabilities, who face 15 or more minutes to reach a tertiary care emergency centre by car (hire or private).
- **SDG 11 (Sustainable Cities and Communities)**
 - 11.2.1: Proportion of population that has convenient access within xxx meters to the integrated public transport network.
 - 11.3.2: Proportion of cities with a direct participation structure of civil society in urban health services planning and management.
- **SDG 13 (Climate Action)**
 - 13.2.2: Total greenhouse gas emissions per year.
 - *Estimated greenhouse gas emission changes from implementing solutions for enhanced accessibility*
 - 13.3.2: Number of countries that have integrated climate mitigation/adaptation into policies, strategies, and planning, for health services accessibility.
- **SDG 16 (Peace, Justice and Strong Institutions)**
 - 16.6.2: Proportion of population satisfied with their travel time to tracer health services.
 - 16.7.1: Gender, age, ethnicity, and disability differences in accessibility compared to historical trends and national distributions (reflecting inclusivity).
- **SDG 17 (Partnerships for the Goals)**
 - 17.16.1: Proportion of the national urban population residing in cities in which patient networks and service providers actively engage in monitoring health services accessibility.
 - 17.18.1: Proportion of the national population residing in cities offering disaggregated health services accessibility data.

If applied to other sectors

- **SDG 2 (Zero Hunger)**
 - 2.1.2: Proportion of urban population living beyond a 15-minute walk from a food dispensary or market.
 - 2.2.2: Proportion of children living in poverty (including extreme poverty) who must walk more than 15 minutes to reach a meal dispensary or school with meal services.
- **SDG 4 (Quality Education)**
 - 4.a.1: Proportion of schools reached by children within 15 minutes from their residence by their available transportation means.
 - 4.5.1: Parity in travel times between (female/male, bottom/top wealth quintile, etc.) travel times to school.

Adapted from:

United Nations (2023). *Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development*. Updated framework by the Inter-Agency and Expert Group on SDG Indicators (IAEG-SDGs). Available at: <https://unstats.un.org/sdgs/indicators/indicators-list/>

2.15 Enabling developments

2.15.1 Reflections on observations

During the preparatory phase, I drew on observations arising from the contrast between the everyday use of consumer smartphone navigation applications (such as Waze, Google Maps, and TomTom), which provide real time travel estimates, and the continued reliance of many planning processes on static or Euclidean measures, or on approaches that fail to account for the effects of traffic congestion.^{3,4,44,53,68,76,161,169,234,314,326,436–438} Having used in car GPS navigation devices since 2003, this disconnect became particularly salient and shaped my motivation to explore more pragmatic, equity-oriented tools for service planning. Personal

exchanges with peers and family, as well as discussions with mentors and colleagues, helped to crystallise these insights.

2.15.2 Intersectoral engagement

My tutor, Dr. Xavier Bonfill, encouraged identifying a director with intersectoral expertise. Following Dr. Lyda Osorio's advice, Professor Ciro Jaramillo joined as thesis director. This strengthened governance and created bridges across health, mobility, and urban planning.

2.15.3 Communication and engagement

From the outset, emphasis was placed on science communication and engagement with non-academic partners. Early collaborators (e.g., J. Hatcher-Roberts, M.B. Ospina, J. Miranda) and forums (Salurbal, Ciudades Cómo Vamos, Global Health Learning Network) helped shape the project and facilitated partnerships. Several of these activities generated visibility through social media highlights and press releases issued by institutions, organisers, national media, and international organisations. Thanks to our collaborators' strong sense of ownership and engagement, we were able to present the project at events and courses in Bogotá, Cali, Copenhagen, Geneva, Lima, London, Medellín, Mexico City, New York, Ottawa, Quito, Rome, Santiago, Valencia, and Washington, DC.

54,152–154,209,227,393,439–442

2.15.4 Validation and team growth

Participation in symposia and international networks expanded the team, bringing in collaborators such as E. Martínez-Herrera, M.O. Bula, and G. Millán. Patient advocates and civic leaders enriched the work with lived experience and institutional memory. A broad mix of experts—ranging from high level civil servants and former municipal, departmental and national authorities to technical health, emergencies, and mobility planners, and patients, —provided perspectives that grounded the project in real policy contexts, and supported an integrated approach to knowledge translation.

9,162,184,190,216,351,368,401,443–445 136,209,241,298,446–450 136,243,276,451 155 152 153,154 135

136,137,244,448,452–456 133,457 251,439

Image 1 was taken in September 2024, when the project's

leadership first met in person at the event at which results were presented to local interest holders and leaders in Cali.



Image 1 September 18, 2024, first leadership encounter at Universidad del Valle, following four years of virtual collaboration.

2.15.5 Complementary training

- 2021–22: Online certificate, *Analysing Health Systems: Lessons from COVID-19* (LSE).
- 2025: Certificate in *Community Engagements, Social Innovation, and Implementation Research for Health Impact* (TDR/WHO).¹³
- Coordinated BMJ–TDR–SESH Global–Sida–PAHO supplement on social innovations for health.¹⁴³

These, along with self-led, uncertified training, contributed to the project’s management and resilience. For example, developing video editing skills, or in managing collaboratively maintained Zotero libraries, which allowed consolidating references from searches, experts, and contributors. Despite the loss of the original scoping review to a ransomware attack, the strategy was reconstructed and

published, and the library evolved into a dynamic shared knowledge base that guided the project and illustrated its participatory ethos.

2.15.5.1 WHO Innovation Challenge and Award

The AMORE Project was presented in the WHO's 2023 LEAD Innovation Challenge. Our proposal, *Driving Towards Equity*, advanced to the final stage and was awarded the WHO LEAD Innovation Award by the Director-General in 2024. This recognition (Image 2) stimulated further institutional interest, including from PAHO and the Inter-American Development Bank. 155 93,210,210,458,459 263,460



Image 2: Certificate issued by the WHO's Director General, with the signature obscured per request of his office

2.15.5.2 National Academy of Medicine of Colombia – 2025 Scientific research awards

On December 10, 2025, the project earned an Honorary Mention at the 2025 Scientific Research Awards of the National Academy of Medicine of Colombia, in a competitive process (Image 3).



Image 3 Honorable Mention to the research project issued by Colombia's National Academy of Medicine

2.15.6 Logo and communications

One of our first priorities was to build a coherent visual identity that would convey the project's ethos and strengthen recognition across platforms. The AMORE logo, designed in 2021 by Ingrid Faber (Figure 20) represents a flower created from location icons, with petals in Sustainable Development Goal colours to highlight people's accessibility needs. Complementary artistic contributions enriched our communications: Adriana Cabal Aulestia's paintings of Cali, volunteer cover designs by Lina María Botero and Paula Saenz, and hand-drawn illustrations by architect Enrique Sinisterra. Together, these elements promoted cohesion among contributors, symbolised the project's intersectoral and equity-driven values, and enhanced the clarity and impact of our public-facing materials.^{12–15,55,238,316–319} We also worked with science communicators to produce visual abstracts, videos, tutorials, and infographics.^{47,185,198,217,219} The project's [LinkedIn page](#) had 2,260 followers by December 31, 2025.



Figure 1: AMORE Project logo and font

2.15.7 Communicating the project

To introduce the project to academic and policy audiences, our first publication was an editorial in *Gaceta Sanitaria* (*Publication 1*) outlining the policy and research challenges addressed by this thesis. The article, “*Improving equity using dynamic geographic accessibility data for urban health services planning*”, summarised the problem of using static measures in planning and positioned dynamic accessibility as a practical alternative. By December 2025, it had received over 8,600 views and ten citations from various disciplines.³

Vol. 36, Núm. 6.
páginas 497-499 (Noviembre - Diciembre 2022)

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Apartados

How then to approach the challenges presented here in a way that promotes equitable accessibility and is scalable?

What if these data were combined with the location of health services and sociodemographic population data to reveal equity and accessibility measurements that inform health services planning and land use?

Other than providing a situational analysis, what else could be done?

Authorship contributions

Funding

EDITORIAL

DOI: 10.1016/j.gaceta.2022.05.001

Open Access

Improving equity using dynamic geographic accessibility data for urban health services planning

Mejorando la equidad usando datos dinámicos de accesibilidad geográfica para la planificación de servicios de salud urbanos

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Este artículo ha recibido

8646 Visitas

10 Citas



Under a Creative Commons license

Publication 1: The editorial presents the policy and research problems.³ (Open the file by clicking the image)

Infographics and a four-minute animation were the first communication products shared with interested parties. These visual resources often served as an accessible entry point, sparking curiosity and encouraging audiences to explore the project in greater depth. Together with testimonies, artwork, and other multimedia elements, they reinforced the project's focus on equity, ensured resonance with civic and institutional audiences, and laid the foundation for broader dissemination and uptake of the findings.^{3,93,94,131–133,236,251,253,461–463}. Testimonies from Commune 18 residents and others convey a compelling presentation of the policy issues.^{133,251,457} Any social or health field worker in these peripheral areas of Cali will find the testimonies relatable (Video 1).



Video 1: Testimonies by Populab describing accessibility challenges.¹³³ (Open the file by clicking the image)

2.15.8 Career-long trajectory (selected reflections)

Earlier professional contributions to participatory approaches, community-oriented primary care, implementation research, systematic reviews, evidence overviews, living reviews, evidence-based guidelines, other knowledge translation tools, capacity development in integrated knowledge translation, evidence-informed policymaking, balancing benefits and harms, and other forms of integrating relevant knowledge to decisions for health policies and actions. These experiences are noted here to document continuity and influence, without adding new data or analyses. A professional profile is available on [LinkedIn](#), and research outputs are documented in [ORCID 0000-0003-2732-5019](#), [ResearchGate](#), [Web of Science Researcher ID](#), [Google Scholar](#), [Scite](#), [SAGE Policy Profiles](#), and [TDRGlobal](#).

2.16 Visual timeline

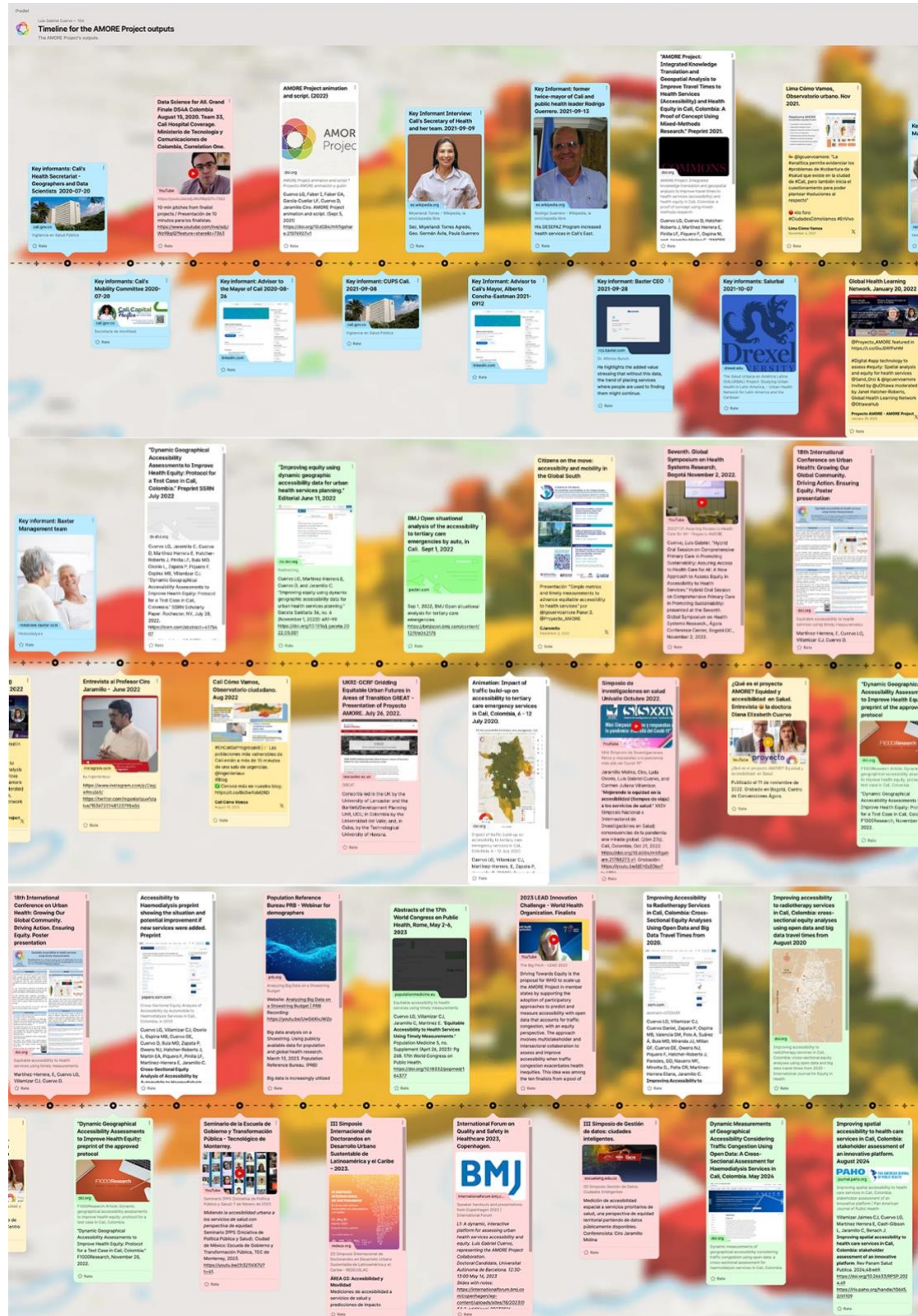
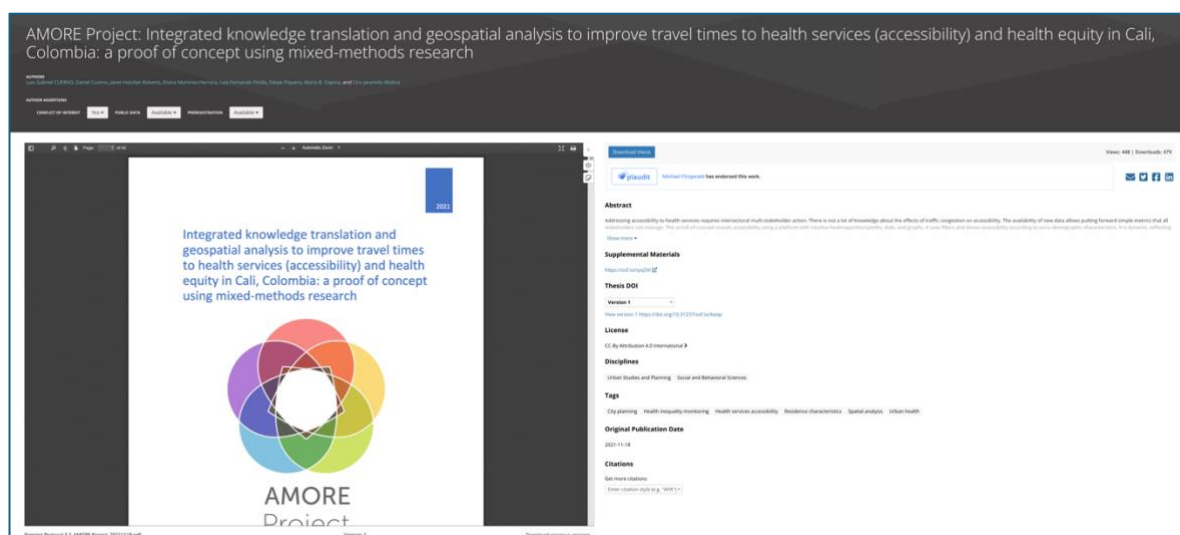


Figure 2: Timeline of project publications and presentations until the radiotherapy report's publication. Colour coding represents meetings with key informants in blue, presentations in red, publications in green, public communications in yellow, preprints and multimedia in white. (Open the file by clicking the image)

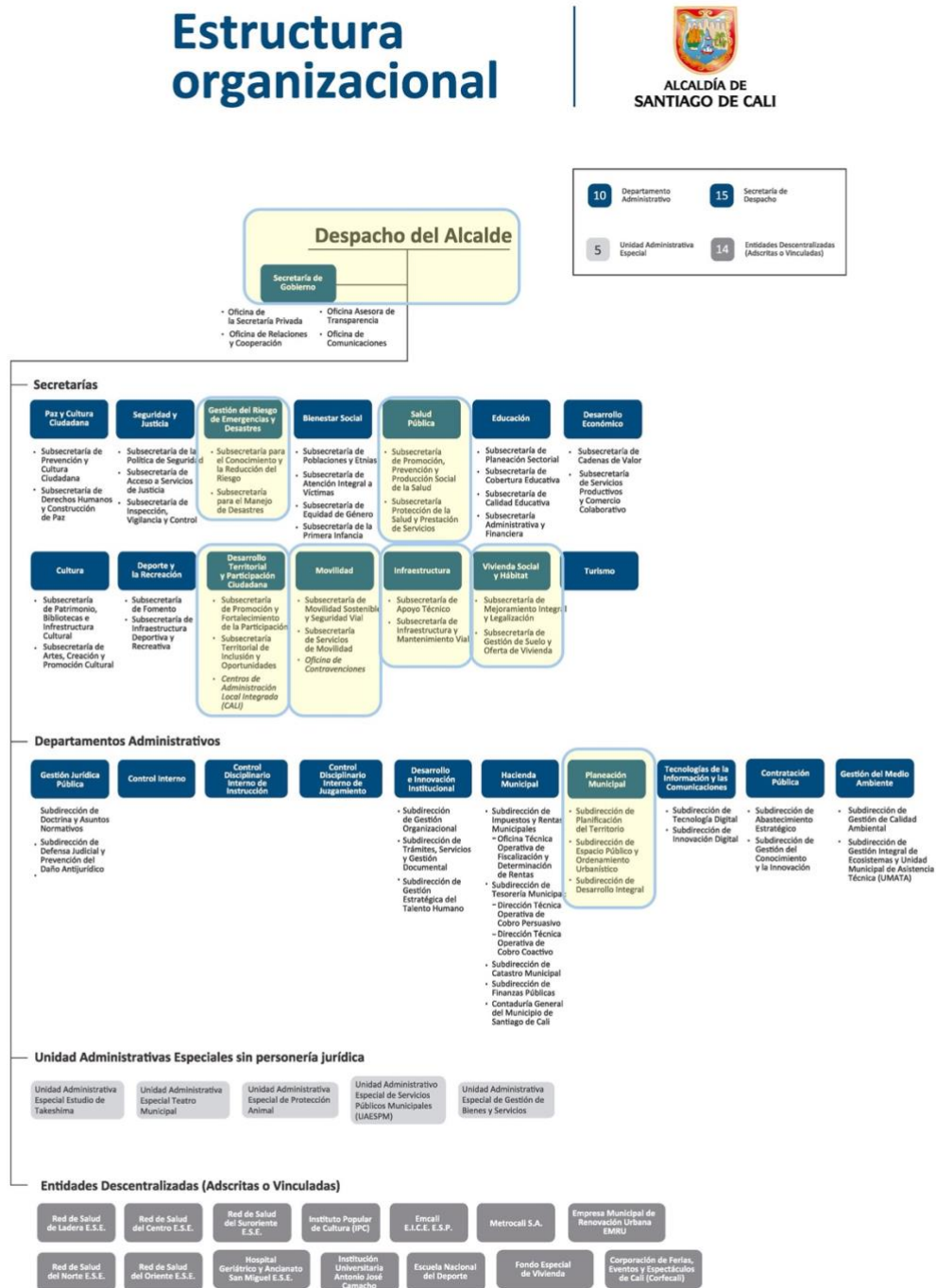
An initial thesis protocol was submitted to my doctoral advisors and published as a preprint. It was deemed too ambitious and reliant on factors beyond my control, such as its transfer into policy, thus it was trimmed to focus on testing the participatory approach to complete the assessments and predictions. The initial protocol was:

- Cuervo LG, Cuervo D, Hatcher-Roberts J, Martínez Herrera E, Pinilla LF, Piquero F, Ospina M, and Jaramillo Molina C. **“AMORE Project: Integrated Knowledge Translation and Geospatial Analysis to Improve Travel Times to Health Services (Accessibility) and Health Equity in Cali, Colombia: A Proof of Concept Using Mixed-Methods Research.”** Preprint. Thesis Commons, November 19, 2021.



Publication 2 – the preliminary thesis protocol ¹⁵⁷ (Open the file by clicking the image)

2.17 Municipal administration official chart.¹³⁹



Organigram retrieved from the website of the Alcaldía de Cali on January 10, 2026. Source: <https://www.cali.gov.co/loader.php?lServicio=Tools&ITipo=descargas&IFuncion=visorpdf&id=73704&pdf=1>
The rectangles highlighting relevant divisions with a yellow shade were added by the doctoral student

(Open the reference's link by clicking on the image). Highlighted entities denote institutions relevant to the scope of this thesis, based on the doctoral student's analytical assessment.

2.18 Reports to the Doctoral Programme's Follow-up Commission

2.18.1 2020

Comprender y transformar la planificación de políticas públicas en salud analizando la equidad y accesibilidad a los servicios de salud combinando el análisis exploratorio espacial con macrodatos: Proyecto AMORE, una prueba de concepto. Doctorando: Dr. Luis Gabriel Cuervo MD, MSc, EMF

¿Cuánto tarda en llegar usted al hospital más cercano? ¿cómo varía esto en el tiempo? ¿cuánto tardan otras personas? ¿cómo planificar las mejoras hacia una accesibilidad más equitativa a los servicios de salud? ¿dónde ubicar nuevos recursos o cómo optimizar la accesibilidad en la planificación de recursos o ante cambios inesperados? ¿Cómo fortalecer el trabajo interdisciplinario en temas de equidad y accesibilidad?

Síntesis

Este proyecto es una prueba de concepto en “comprender para transformar”, también como conocido como “traducción del conocimiento”. Esta prueba es sobre los efectos de llegar a acuerdos en políticas de impacto para la equidad en salud mediante deliberaciones intersectoriales y de otras partes interesadas. La equidad es el eje de las discusiones que en esta prueba son alrededor de mejorar la accesibilidad a los servicios de salud, avanzando así los Objetivos de Desarrollo Sostenible de las Naciones Unidas (ODS). Entre los actores principales están los sectores de gobierno municipal, planeación, salud pública, y movilidad.

Este enfoque avanza los objetivos y promueve los valores que las políticas mundiales, regionales, nacionales, y locales. La prueba de concepto se hará en la ciudad de Santiago de Cali, en Colombia. El instrumento fundamental para la prueba de concepto es el presentar información válida, oportuna, relevante, y sensible a las variaciones en las condiciones, durante la planificación y desarrollo de políticas públicas. El concepto es poder informar el trabajo intersectorial y es susceptible de replicarse en otras circunscripciones, aspectos de política pública, y áreas de trabajo. Estudiaré las percepciones de decisores y expertos en los diferentes niveles y sectores del gobierno distrital, y con otros actores relevantes.

Preguntas generales: ¿permite la información compartida sobre los efectos en la equidad guiar el trabajo intersectorial de planificación y política pública municipal? ¿qué efectos tienen sobre la planificación la disponibilidad de información actualizada que ilustra el impacto de la movilidad sobre la accesibilidad a los servicios? (Ilustración 1)

¿Qué se sabe?

Las herramientas para comprender y transformar las prácticas y políticas en sistemas de salud se han desarrollado, validado, e implementado en diversos países con desarrollos importantes en el siglo XXI. La implementación de la Agenda 2030 de las Naciones Unidas requiere de un enfoque interdisciplinario y trabajo colaborativo, de forma que pueda avanzarse en la equidad y alcance de los Objetivos de Desarrollo Sostenible. La participación de actores claves en los procesos tiende a incrementar la apropiación y relevancia de las herramientas, su relevancia y adopción.

¿Qué aportará el estudio?

Existen pocas plataformas e instrumentos para llevar a la práctica el trabajo interdisciplinario a nivel de gobiernos, de forma que centren a los sectores en los principios generales como la equidad y accesibilidad. El estudio incluye el desarrollo de una plataforma digital que integra datos relevantes a equidad en la accesibilidad a los servicios de salud, y plantea escenarios prácticos de planificación para ambos aspectos a corto, mediano, o largo plazo. También permite contar con datos actuales que reflejen cambios en la equidad y accesibilidad ante cambios en las condiciones de los servicios de salud y de movilidad (v.g. nuevas vías, cierre de vías o instituciones, cambios en los patrones de tráfico, emergencias y desastres).

¿Qué diferencia puede hacer?

En el mejor escenario, la prueba de concepto puede llevar a que las iniciativas intersectoriales se centren en resolver las inequidades en la accesibilidad, por ejemplo. La prueba de concepto permitirá aprender de las necesidades de quienes inciden en la planificación en los gobiernos, dando pie a desarrollos ulteriores y el uso del enfoque en otros aspectos del sector salud, y más allá. Ante una emergencia o un cambio de las condiciones, las autoridades pueden más fácilmente optimizar los recursos, modelar escenarios, e incrementar el impacto de sus opciones.

Ilustración 1 Integración de los SDGs más relevantes al proyecto

Como parte de la prueba de concepto se está desarrollando una plataforma (Ilustración 2) que integra información digital de movilidad -con los tiempos de viaje a los servicios usados como referencia, con las bases de datos que aportan información socio-demográfica de la población y que incluye varias de las características identificadas por (la Colaboración) Cochrane para estratificar oportunidades de equidad en los desenlaces (PROGRESS+) tales como: el sitio de residencia, estrato socio-económico, género/sexo, educación, edad, discapacidad.



Esto permite hacer una analítica:

- Descriptiva: estableciendo los tiempos de viaje a los servicios de salud y visibilizando cómo varía la accesibilidad en las horas y días de la semana
- Diagnóstica: de la situación de equidad, exponiendo las variaciones de la cobertura por zona geográfica y por características sociodemográficas, algo que los planificadores consultados encontraron novedoso.
- Predictiva: ilustrando el impacto en equidad y accesibilidad según los horarios y distribución de los servicios, al eliminarse o agregarse servicios (v.g. en una emergencia o congestión). Anticipando el impacto de cambio en las condiciones de tráfico, de prestación de servicios, o a medida que cambia la población (cambios del tráfico, servicios, población)
- Prescriptiva: identificando ubicaciones de nuevos recursos donde se optimiza la accesibilidad y se reduce el uso de recursos, por ejemplo, al agregar servicios o cambiar las condiciones de accesibilidad. Permite que instituciones, aseguradores, la sociedad civil, o quienes hacen la planificación, evalúen opciones y modelen el impacto (v.g. Ilustración 3).

Preguntas específicas

¿Cómo afecta la información dinámica sobre equidad en la accesibilidad a los servicios de salud los planes y políticas urbanas? ¿Cómo incide sobre la respuesta a emergencias y desastres?

¿Qué características consideran útiles los usuarios en el prototipo/plataforma integradora de datos?

¿Qué características tienen aplicación a nivel de políticas de gobierno o trabajo intersectorial?

¿Cuáles son los efectos sobre el trabajo intersectorial de contar con datos dinámicos de equidad y accesibilidad? ¿Qué diferencias perciben frente a los mecanismos tradicionales?

¿Qué se necesita para la adopción y escalamiento de las metodologías propuestas en la planificación para la salud pública, y para otros sectores?

¿Qué consideraciones tendrían para aplicar o estandarizar estas metodologías a nivel local, departamental, o nacional?

Desarrollos (febrero – agosto, 2020)

- Establecí grupos de consulta y colaboración, incluyendo potenciales usuarios en la planificación municipal, incluyendo expertos en temas de salud pública, movilidad, analítica, logística, respuesta a emergencias, gestión municipal, tecnologías digitales, urbanismo, innovación en salud, programación.
- Presenté el concepto y el prototipo de la Plataforma AMORE (Ilustración 2) a los asesores técnicos de alto nivel en salud pública, movilidad, alcaldía municipal, tecnologías y comunicaciones (ministerial)
- Identifiqué las fuentes de información georreferenciadas, datos básicos, servicios de referencia (24 instituciones) que usa la Plataforma AMORE
- Establecí una librería virtual de referencias relevantes a la tesis
- Seleccioné ejemplos y escenarios ilustrativos de la prueba de concepto: acceso en auto a urgencias médicas de alta complejidad a diferentes momentos, en una situación catastrófica; variaciones en el acceso a servicios ambulatorios de uso regular, como son la hemodiálisis y radioterapia, con ejemplos de los recursos involucrados
- Avancé en la optimización de muestreos, para:
 - tiempos de viaje por día y franjas horarias, estableciendo conglomerados horarios y reduciendo las consultas en 95.2% sin sacrificios sustanciales en la precisión.
 - puntos de origen de las consultas identificando los *centroides poblacionales* para las Zonas Administrativas de Transporte o sectores de la ciudad, reduciendo en 96.3% el número orígenes a consultar.
 - puntos de destino (hospitales/entidades) agrupando por proximidad, reduciendo las consultas en 26%.
 - Establecimiento del almacenamiento e indización de datos para optimizar el uso de la información disponible.
- Selección del modelo para optimizar la cobertura si se agregan nuevos recursos (hospitales ofreciendo alta complejidad, sillas de diálisis, servicios de radioterapia)
- Establecimiento del almacenamiento e indexación de datos para optimizar su uso.
- Desarrollo y prueba del prototipo de la Plataforma AMORE (Ilustración 2) que integra datos de movilidad (con variaciones en franjas horarias y días), con las características sociodemográficas poblacionales, y los servicios de salud relevantes a los ejemplos.
- Establecí y lidero grupos de trabajo en
 - **analítica**, para el modelamiento y optimización del muestreo y las soluciones ante diferentes escenarios. Reuniones semanales de trabajo.
 - **programación**, para traducir los conceptos en una herramienta de fácil operación y entendimiento, que integre las variables seleccionadas y opere con diferentes sistemas (OS, Android, Windows, Linux). Desarrollo de la arquitectura de la Plataforma AMORE y del almacenamiento de datos. Reuniones de trabajo varias veces por semana.
 - **movilidad**, para identificar los retos que afrontan y las particularidades en salud. Reuniones y entrevistas con los asesores principales de movilidad, y la subsecretaría

Comprender y transformar la planificación de políticas públicas en salud analizando la equidad y accesibilidad a los servicios de salud combinando el análisis exploratorio espacial con macrodatos: Proyecto AMORE, una prueba de concepto. Doctorando: Dr. Luis Gabriel Cuervo^{MD, MSc, EMF}

- **equidad**, para refinar los análisis ciñéndose a los estándares internacionales. Tres reuniones de planificación en el desarrollo del prototipo
- **salud pública**, para ajustarse a las particularidades del sistema de salud local y nacional. Reuniones quincenales/mensuales, consulta al Centro Regulador de Urgencias, Emergencias y Desastres de la Secretaría de Salud Departamental del Valle del Cauca.
- **gobernanza y rectoría de la cosa pública municipal**, para identificar necesidades y orientaciones específicas a la gestión y planificación municipal.
- Se validó y presentó el prototipo de la Plataforma AMORE en la convocatoria DS4A del Ministerio de Tecnologías de la Información y Comunicaciones de Colombia y fue reconocida entre las 5 mejores (de 92 plataformas que compiten) con la ministra y el viceministro de Economía Digital interesados en la aplicación de la propuesta en planeación nacional.
- He participado en capacitaciones y eventos relacionados al tema de trabajo con entidades internacionales y nacionales (Colombia) cubriendo temas tales como movilidad, equidad, accesibilidad, salud pública, innovación social, traducción del conocimiento, y desarrollo de políticas de ciencia, tecnología e innovación para la salud.
- Desarrollé ayudas visuales multimedia, gráficos informativos, y otras herramientas de comunicación

Ilustración 2 interfaz del prototipo de la Plataforma AMORE ilustrando: (1) los filtros (por estrato socioeconómico, sexo, discapacidad, enfermedad, nivel educativo, edad); (2) los datos demográficos, de cobertura según el nivel de tráfico, tiempos de viaje, hospitales habilitados para el análisis; (3) la optimización de nuevos servicios maximizando cobertura



Opción	Bajo Ingreso	Total Urbano
Inacción	26%	48%
+	67%	73%
+	58%	68%
+	78%	85%
+	67%	79%
+	85%	90%

Ilustración 3 Impacto repotenciar servicios(+) o adicionar hospitales (+) sobre la cobertura municipal general y entre los estratos socioeconómicos más bajos.

Comprender y transformar la planificación de políticas públicas en salud analizando la equidad y accesibilidad a los servicios de salud combinando el análisis exploratorio espacial con macrodatos: Proyecto AMORE, una prueba de concepto. Doctorando: Dr. Luis Gabriel Cuervo^{MD, MSc, EMF}

Plan de trabajo (septiembre 2020 – 2021)

- Aprobación/ Exención del Comité de Ética
- Registrar el proyecto de investigación
- Finalizar el prototipo y desplegar la Plataforma AMORE (interfaz inglés/castellano)
- Publicar el protocolo de investigación
- Publicar de la metodología de muestreo y optimización
- Muestreo final de origen-destino con la muestra seleccionada
- Integrar datos en la Plataforma AMORE y capturar datos para el análisis cuantitativo
- Modelar la optimización de nuevos servicios
- Desarrollar las entrevistas semiestructuradas y obtener información cualitativa
- Entrevistar actores clave a nivel local, nacional, e internacional.
- Desarrollar el análisis de equidad
- Probar la metodología en la planificación municipal
- Identificar soluciones a corto, mediano, y largo plazo con la autoridad municipal.
- Explorar la utilidad con Entidades Promotoras de Salud, Instituciones Prestadoras de Servicios de Salud, y asociaciones de usuarios.
- Evaluar con las partes interesadas la utilidad
- Emitir recomendaciones ante la transformación política de Cali en un Distrito Especial, con seis localidades.
- Publicar el informe de investigación con recomendaciones específicas para desarrollar el campo de estudio, implementar los resultados relevantes, y de ser apropiado, escalar el modelo tanto en cobertura nacional como internacional, y a otros sectores de gobierno y sociedad.
- Publicar el trabajo de tesis doctoral.

Director de tesis:

Dr. [Ciro Jaramillo Molina](#), Profesor Asociado de la Escuela de Ingeniería Civil y Geomática. Director del Grupo de Investigación en Transporte, Tránsito y Vías (GITTV). Fue vicedecano de investigación y posgrados, y Director del Doctorado de la Facultad de Ingeniería de la Universidad del Valle. Ha publicado capítulos de libros de referencia, y artículos en revistas indizadas y revisadas por pares. Obtuvo su título como Doctor en Ingeniería de Transporte en la Universidad Politécnica de Valencia y su Posdoctorado en Urbanismo y Ordenación del Territorio en la Universidad de Granada. Asesor de la Alcaldía de Cali, la Secretaría de Infraestructura, la Secretaría de Movilidad, y otras entidades gubernamentales.

Doctorando:

Dr. [Luis Gabriel Cuervo Amore](#), Médico Especialista en Medicina Familiar y Magíster en Epidemiología Clínica, pionero de la Colaboración Cochrane en Colombia, con amplia experiencia internacional en traducción del conocimiento, gestión de la investigación, y políticas de investigación para la salud.

2.18.2 2021



Acciones intersectoriales apoyadas en analítica y tecnologías digitales que revelan y optimizan la accesibilidad a servicios esenciales de salud.

Doctorando: Luis Gabriel Cuervo

Equipo colaborador: Luis Gabriel CUERVO (Doctorando), Ciro JARAMILLO MOLINA (director de tesis), Xavier BONFILL i COSP (tutor). Otros coautores del protocolo: Daniel CUERVO, María Beatriz OSPINA, Luis Fernando PINILLA, Janet HATCHER ROBERTS, Felipe PIQUERO VILLEGAS.

Website y apoyo tecnológico: iQuartil S.A.S.

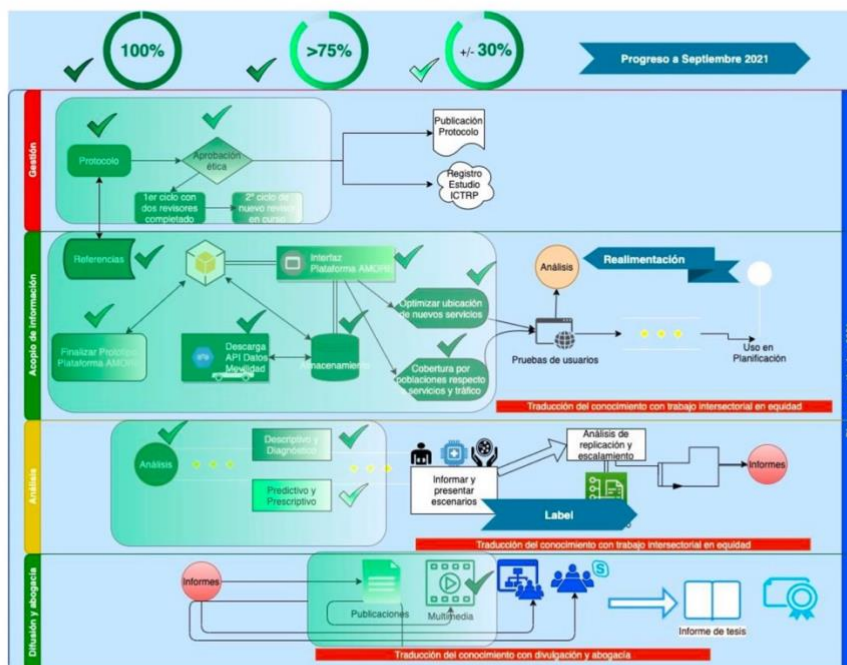
"El reto para las ciudades de Latinoamérica y el Caribe es que la tecnología visualice las necesidades de sus ciudadanos, sobre todo las de los más vulnerables". Anasella Acosta, Smart Cities & Inequidad, Forbes Centroamérica, Número 82, julio-agosto 2021, Página 12. https://issuu.com/forbeslatam/docs/forbes_rd_julio_12

¿Cuánto tardaría en alcanzar el hospital más cercano? ¿cómo varía esto con el tráfico? ¿cómo afecta esto la equidad en salud? ¿quiénes pagan desproporcionadamente por ello? ¿dónde ubicar nuevos recursos? ¿cómo optimizar la accesibilidad? ¿cómo planificar o responder a cambios en la población, infraestructura, o condiciones de tráfico? ¿cómo hacer el trabajo intersectorial?

Desarrollos (agosto 2020 a 6 de septiembre 2021)

En verde, las áreas de desarrollo a agosto de 2021

Ilustración 1 Plan y progreso Proyecto AMORE a septiembre 2021



En la Ilustración 1, se resume el progreso desde la 1ª Comisión de Seguimiento, con los avances sombreados en verde. Inicié mi doctorado en febrero de 2020 y desde la Comisión de 2020 he avanzado especialmente en:

- **Protocolo:** se escribió el protocolo en inglés y español y se cerrará cuando termine la revisión del Comité de Revisión Ética y Metodológica, del Instituto Nacional de Salud de Colombia (CEMIN). Siendo esta una investigación de implementación de riesgos mínimos, hecha con datos



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públicamente disponibles y entrevistas a funcionarios públicos en su capacidad profesional, es posible publicarlo sin revisión ética. Para ampliar las oportunidades de participación ciudadana, captar historias de usuarios de los servicios, y promover la apropiación, se optó por pedir una evaluación del CEMIN. Sometimos el proyecto el 3/06/21 y el 7/07/21 contestaron pidiendo explicaciones y ajustes expuestas por dos revisores externos. Se sometió la respuesta y versión revisada el 18/07/21. El CEMIN envió el proyecto a un tercer revisor y el 30/08/21 sometió una nueva solicitud de aclaraciones que atenderemos después de la 2ª Comisión de Seguimiento. Si CEMIN aprueba, se publicará el protocolo incluyendo historias de usuarios; alternatively, se publicará restringiéndose a entrevistar funcionarios.

- **Referencias:** Para agosto 2021 la [biblioteca virtual del Proyecto](#) contaba con 796 referencias.
- **Prototipo:** El 2º Prototipo de la Plataforma AMORE estará disponible a finales de septiembre de 2021 en su [portal](#) y se presentará a la Comisión el 22 de septiembre de 2021. Tiene una sección de *análisis situacional* y otro de análisis predictivo y prescriptivo. La sección de Análisis situacional fue validada y aportó los datos usados en la infografía y la animación de tiempos de viaje para hemodiálisis. Esta reveló la magnitud de del problema y permitió iniciar una propuesta de informes de la línea de base de accesibilidad a servicios radioterapia, hemodiálisis, y de urgencias en instituciones de alta complejidad.

Ilustración 2



También se reveló que el tráfico impacta más duramente los tiempos de viaje y la accesibilidad de las gentes más pobres y de quienes viven en casas-fincas en la periferia urbana. En general, las gentes pobres pagan más tanto en gastos directos como indirectos para acceder los servicios. Estos son ejemplos de [datos nuevos](#) no disponibles en estudios tradicionales de origen-destino.

Si se contrastan la Ilustración 5 y la Ilustración 4 se evidencia cómo el tráfico grava más los sectores más bajos y periféricos (información que aportan las coropletas de la Plataforma)

- **Patrones de tráfico:** se identificaron los patrones de tráfico en la zona urbana de Cali en 168 franjas horarias, durante la 3ª semana de septiembre (tiempo usual para hacer estimados de tráfico), semana del período escolar y sin festivos. Se identificaron 9 conglomerados de niveles de tráfico en orden creciente desde 1 (flujo libre) a 9 (congestión máxima). La moda en Cali es el nivel 8, con 40 franjas horarias en la semana.

Los datos de la Plataforma AMORE revelaron inequidades en varios frentes y se presenta en la **Error! Reference source not found.** e Ilustración 3.

Ilustración 3



Infografía: Los datos permitieron completar una infografía del proyecto en [inglés](#) y [español](#) (**Error! Reference source not found.**), el cual fue desarrollado con aportes de potenciales usuarios, coautores, y expertos en comunicación científica. La infografía y animaciones completan el multimedia en esta fase del proyecto; nuevos recursos multimedia se producirán con los resultados del análisis situacional, los estudios de optimización e identificación de opciones, los hallazgos de la fase de iKT, y otros informes de tesis.



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Ilustración 5

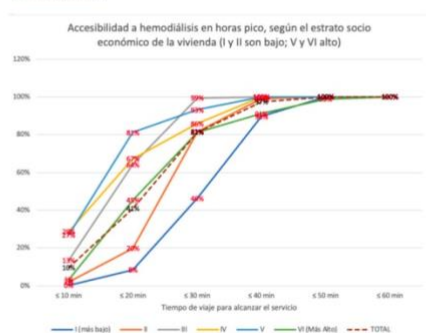
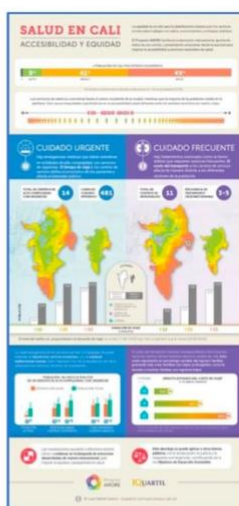


Ilustración 4



Ilustración 6



Multimedia:

- Animación: Para comunicar el objetivo general del proyecto, se desarrolló una animación informativa y subtitulada (< de 4 min) en **español e inglés**. Los videos pueden accederse pinchando en las imágenes correspondientes.



También se hicieron animaciones ilustrando **tiempos de viaje a hemodiálisis**

la sociedad civil (incluyendo academia), y representantes de prestadores y financiadores de los servicios de salud. En la validación participaron coautores, estudiantes de arte y diseño, dos profesionales especializados voluntarios (Profesora de Pediatría con magister en Género, sociedad y Política)

Estos son los vínculos a los cuestionarios de línea de base para:

- Urgencias en instituciones de salud de alta complejidad
- Servicios de uso frecuente en enfermedades de alto costo (hemodiálisis y radioterapia)
- Participantes de la planificación urbana.
- Verificación de datos de las fuentes y actualización en la Plataforma AMORE:

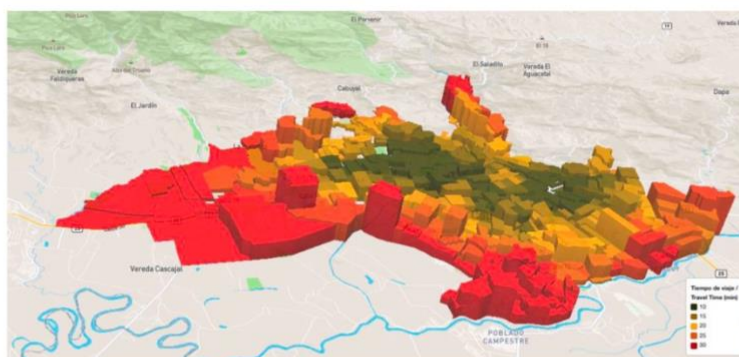


Acciones intersectoriales apoyadas en analítica y tecnologías digitales que revelan y optimizan la accesibilidad a servicios esenciales de salud.

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- **Tiempos de viaje, Google API:** En noviembre de 2021 se actualizaron los tiempos de viaje de la plataforma para reflejar el impacto de la pandemia Covid-19.
- **Entidades prestadoras de los servicios:** En enero de 2021 se verificaron los servicios de salud del Registro Especial de Prestadores de Servicios de Salud y se integraron en la Plataforma AMORE. Aparecen en [este mapa virtual](#), e incluyen 14 servicios de urgencias en hospitales de alta capacidad, 5 servicios de radioterapia, y 11 servicios de hemodiálisis con 370 sillas.
- **Datos censales:** en octubre 2020 se actualizaron los datos censales del 2018 con los datos georreferenciados ajustados del Departamento Nacional de Estadística.¹
- **Categorización de la educación:** entre enero de 2021 se consultó a la experta en el sistema de educación colombiana, Dra. Myriam Rosero, logrando una simplificación de las [categorías de educación en Colombia](#) y datos censales, más armónica con la taxonomía internacional.
- **Datos sociodemográficos actualizados:** se obtuvieron datos oficiales sobre situación de empleo y migración, para 2021.(2) ²
- Se desarrolló la identidad del proyecto reflejándola en un logotipo y marca del Proyecto AMORE. El logotipo se registró y se acordó con IQuartil S.A.S. facilitar el desarrollo, escalamiento, y replicación de la Plataforma AMORE. El logotipo se integró a la estrategia de comunicación.
- **Interfaz 2.0 de la Plataforma AMORE:** Se produjo el prototipo bilingüe avanzado de la Plataforma AMORE incorporando variables de etnicidad, ajustando las visualizaciones y categorías de los datos, y agregando predicciones para hemodiálisis y radioterapia. La Ilustración 7 presenta la distribución poblacional según la accesibilidad a servicios de hemodiálisis en horas pico, cuando el 43% de la población urbana puede acceder un servicio en 20 minutos, y esta cifra es 10% para el estrato económico más bajo. El mapa (sur a la izquierda, occidente arriba, Ilustración 7) visibiliza la relación ente accesibilidad y densidad poblacional (altura de los sectores); la consola en la Plataforma AMORE aporta datos sobre accesibilidad según las características sociodemográficas recomendadas por [PROGRESS Plus](#) y directrices de informes de investigación.

Ilustración 7 Coropletas de Cali (de sur a norte) reflejando accesibilidad a hemodiálisis y densidad poblacional



¹ DANE. Información técnica y omisión censal 2018, aspectos conceptuales y metodológicos. 2019. Disponible en:

<https://www.dane.gov.co/index.php/estadisticas-por-tema/demografia-y-poblacion/censo-nacional-de-poblacion-y-vivienda-2018/informacion-tecnica>

² DANE, Sistema Estadístico Nacional - SEN. Información del DANE para la toma de decisiones regionales: Cali - Valle del Cauca. Colombia - Cali: DANE; 2021 Mar. Pg. 223. Disponible en <https://www.dane.gov.co/index.php/estadisticas-por-tema/informacion-regional/informacion-estadistica-desagregada-con-enfoque-territorial-y-diferencial/informacion-del-dane-para-la-toma-de-decisiones-en-departamentos-y-ciudades-capitales>



Acciones intersectoriales apoyadas en analítica y tecnologías digitales que revelan y optimizan la accesibilidad a servicios esenciales de salud.

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- **Análisis preliminares:** con estos se comenzó a redactar el primer artículo de la serie de tres que describirán los valores de base sobre accesibilidad a los servicios de salud, para la población urbana de Cali. Para esto, se siguen las directrices de **STROBE** para estudios observacionales.
- **Planificación de las series de artículos:** se planificó para sacar las siguientes colecciones, en el curso de los próximos tres años, cubriendo los tres ejemplos del estudio relevantes a atención frecuente y atención urgente, y desarrollando así toda una línea de investigación:
 - Accesibilidad a los servicios de salud para la población urbana de Cali, 2021
 - Uso de datos georreferenciados y optimización de servicios de salud en Cali
 - Percepciones entre actores de la planificación urbana, respecto a la accesibilidad a los servicios de salud, y las alternativas para incidir sobre ella.
 - Resultados de un ejercicio de traducción integrada del conocimiento en la planificación urbana de Cali, con miras a ampliar la participación ciudadana e integrar la equidad en salud en la agenda de trabajo.
- Participación en eventos relevantes y seguimientos con el director de tesis:
 - 27 reuniones de seguimiento con el Doctor Ciro Jaramillo Molina en los últimos 12 meses
 - Seminarios:
 - Seminario de análisis de autocorrelación espacial (16/10/2020)
 - Seminario de análisis exploratorio con cartografía interactiva (09/10/2020)
 - Análisis espacial con cartografía temática y uso de GeoDa (02/10/20)
 - Características de las medidas de accesibilidad (25/9/2020)
 - Índices de ciudades modernas (01/09/2020)
 - Capacitación en obtención de datos de velocidad Plataforma Google (25/08/2020)
 - Limpieza de datos del DANE
 - Cursos varios para uso de la plataforma participativa Miro.
 - Cursos varios para uso profesionalizado de Zoom integrándolo con Miro.
 - Cursos de protección de la propiedad intelectual con UAB [M034569] (27/03/21) y con la Dirección Nacional de Derechos de Autor, de Colombia.
- **Luis Gabriel CUERVO** (LGC), Investigador principal y autor corresponsal. Estudiante de Doctorado en Metodología de Investigación Biomédica y Salud Pública, Universidad Autónoma de Barcelona, Cataluña, España. Doctor en Medicina y Cirugía y Magister en Epidemiología Clínica de la Pontificia Universidad Javeriana en Bogotá. Especialista en Medicina familiar de la Universidad del Valle de Cali. Email: LuisGabriel.Cuervo@e-campus.uab.cat ó LGCuervo@email.com; ORCID ID: <https://orcid.org/0000-0003-2732-5019>
- **Daniel CUERVO** (DCA), iQuartil SAS. Ingeniero Industrial de la Universidad de los Andes con un MBA de London Business School (Lista del Decano), analista de datos certificado, con experiencia en análisis, modelado matemático e inteligencia empresarial. ORCID ID <https://orcid.org/0000-0002-3323-9865>
- **Luis Fernando PINILLA** (LFP), Consultor senior en iQuartil SAS. Ingeniero industrial de la Escuela Colombiana de Ingeniería Julio Garavito. Magister en Ingeniería Industrial y Optimización, Universidad Javeriana. Científico de datos certificado. Profesor de Simulación y Modelado en la Universidad de la Sabana, Bogotá.
- **María Beatriz OSPINA** (MBO), Profesor Asistente, Facultad de Medicina y Odontología, Universidad de Alberta, Edmonton, AB, Canadá. Cátedra de Investigación de Canadá de Nivel 2 en Curso de Vida, Entornos Sociales y Salud. Gobierno del Canadá. Embajadora de Investigación en Salud de mujeres y niños del Instituto de Investigación de la Salud de la Mujer. Titulada en Psicología; Magister en Epidemiología Clínica; Doctora en Ciencias de la Salud Pública. Estudios adicionales de posgrado en Epidemiología y Ciencias Sociales, Becaria Visitante en Revisiones Sistemáticas y Evaluación de Tecnología de la Salud; Certificados de Traducción del Conocimiento y Supervisión de Posgrado. ORCID ID: <https://orcid.org/0000-0001-9305-7521>
- **Janet HATCHER-ROBERTS** (JHR), Codirectora del Centro Colaborador de la OMS en Traducción del conocimiento, Evaluación de Tecnologías en Salud para la Equidad, Instituto de Investigación Bruyère, Universidad de Ottawa, Escuela Adjunta de Epidemiología y Salud Pública de la Universidad de Ottawa
- **Felipe PIQUERO VILLEGAS** (FPV). Abogado con experiencia específica en derecho administrativo y legislación de atención médica. Defensor del consumidor del carcinoma de células renales, hemodiálisis y trasplante renal. Autor del libro "Oportunidades en medio de la incertidumbre".
- **Xavier BONFILL i COSP** (XBC), Universidad Autònoma de Barcelona. Médico. Especialista en Oncología Médica del Hospital Vall d'Hebron. Magister en Salud Pública de la Universidad de Columbia. Especialista en Medicina Preventiva y Salud Pública, Ministerio de Sanidad, Servicios Sociales y Equidad, España. ORCID ID: <https://orcid.org/0000-0003-1530-3509>
- **Ciro JARAMILLO MOLINA** (CJM), Profesor Asociado, Escuela de Ingeniería Civil y Geomática de la Universidad del Valle. Ingeniero Civil de la Universidad del Valle. Diplomado en Estudios Avanzados (DEA) y Doctor en Ingeniería de Transporte por la Universidad Politécnica de Valencia en España. Postdoctorado en Urbanismo y Planificación Espacial de la Universidad de Granada en España.

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2.18.3 2022



Evaluaciones dinámicas de accesibilidad geográfica para mejorar la equidad en salud: prueba en Cali, Colombia. Doctorando: Luis Gabriel Cuervo

Equipo coordinador: Luis Gabriel CUERVO (Doctorando, Líder), Ciro JARAMILLO MOLINA (director de tesis), Eliana MARTÍNEZ HERRERA (codirectora de tesis), Xavier BONFILL i COSP (tutor).

Coautores del protocolo (voluntarios): Daniel CUERVO, Luis Fernando PINILLA, Janet HATCHER ROBERTS, María Olga BULA, Lyda OSORIO, Pablo ZAPATA, Felipe PIQUERO VILLEGAS, María Beatriz OSPINA, Carmen Juliana VILLAMIZAR JAIMES (Gerente de Proyecto).

[Website en iQuartil S.A.S.](#) @Proyecto_AMORE Animación informativa: [vídeo de 4 min](#)

Desarrollos (del 9 de sept 2021 al 10 de septiembre 2022)

La situación del proyecto doctoral se ilustra en la Ilustración 1 y se presenta la Ilustración 2 con la situación a septiembre 2021, para referencia.

Mi doctorado inició en febrero de 2020. La Ilustración 2 presenta el progreso a septiembre 2022. Hemos completado la recolección de datos y las publicaciones de resultados avanzan y exceden el requerimiento para graduación; los primeros resultados fueron publicados en BMJ Open (Q1) el 1 de septiembre; previamente se publicó una editorial exponiendo el tema, retos y oportunidades. Necesitamos apoyo de UAB para aprovechar los acuerdos que permitan publicar en acceso abierto.

Consolidamos los equipos de trabajo para los tres escenarios presentados: urgencias de alta complejidad, hemodiálisis, y radioterapia. El proyecto ha tenido amplia difusión multisectorial con participación de representantes de la gobernanza constitucional (autoridades), operativa (usuarios y prestadores de los servicios) y colectiva (academia, veedurías, representantes de pacientes y otros actores comunitarios). Las dos publicaciones han superado 1,500 descargas cada una.

En el año venidero (2022 – 2023) avanzaremos las publicaciones pendientes de resultados, artículos de opinión y metodológicos. Promoveremos la integración de indicadores basados en tiempos dinámicos y de accesibilidad en la planificación urbana, de servicios, y del ordenamiento territorial, y marcos políticos.

Este último año hemos divulgado el proyecto en espacios ciudadanos (v.g., Red de Ciudades Cómo Vamos: *Lima Cómo Vamos*; *Cali Cómo Vamos*), educativos (*Global Health Learning Network*, *II Simposio Internacional de Doctorandos en Desarrollo Urbano Sustentable en Latinoamérica y el Caribe [concurso]*, *LIESU-FNSP*) y en reuniones con autoridades, incluyendo reuniones con la Secretaría de Salud de Cali y su equipo. Invitación de la Secretaría de Salud de Bogotá para noviembre 2022.

Publicamos una editorial de amplia difusión, exponiendo los retos que atiende el proyecto doctoral y la disrupción transformadora del trabajo intersectorial ante el desarrollo de una nueva línea de investigación.

Sufrimos inconvenientes importantes con la disrupción de servicios digitales de la UAB que nos llevaron a reorganizar elementos del proyecto, centrándonos en la generación y uso de los datos de accesibilidad.

- **Protocolo:** El CEEAH-UAB recibió el protocolo en febrero 2022 y pidieron clarificación sobre si se trataba de investigación en humanos. No es investigación en humanos; es un proyecto de investigación participativa con diseño centrado en personas. Se reescribió el protocolo para simplificarlos y ofrecer claridad, sometiéndolo nuevamente al CEEAH-UAB en junio de 2022. Coincidimos con cambios en los procesos y nuevos requerimientos tecnológicos y administrativos que resultaron complejos y tardados, requiriendo varias reuniones virtuales técnicas y administrativas. El protocolo fue recibido el 25 de julio de 2022 y está agendado para revisión el 16 de septiembre de 2022.
- El 25 de junio de 2022 el Comité de ética de la Facultad de Ingeniería de la Universidad del Valle emitió un concepto favorable (aval CEIFI: 010-2022) como aparece en el protocolo [pre-impreso en SSRN](#). Se notificó a CEEAH-UAB.

Los editores de BMJ Open concordaron que el estudio sometido no constituye investigación en humanos y descartaron incluir la aprobación de CEIFI para evitar confusión. Asimismo [medRxiv](#), que publicó el [preimpreso](#) del artículo en febrero 2022, vio innecesaria la aprobación ética.



Referencias: La biblioteca virtual del Proyecto, accesible a los autores, cuenta con 1446 referencias, doblando las disponibles en 2021 (796 referencias).

- **Plataforma AMORE:** Se completó la Plataforma AMORE y su validación. Está disponible desde febrero de 2022 para integrantes del grupo colaborador, previo acuerdo de confidencialidad. Con la publicación de resultados en BMJ Open hicimos públicamente disponible una interfaz específica a ese informe que permite interactuar con los datos, probar escenarios, verificar o retar supuestos.

La Plataforma interactiva permite análisis situacionales, predictivos y prescriptivos que serán informados en las publicaciones del estudio. Muestra el potencial de mejorar la accesibilidad y las ubicaciones en las que nuevos servicios la optimizan. Los datos censales están ajustados al 2020 (por crecimiento intercensal y migración) que se corresponde con los datos de servicios y los tiempos de viaje para las semanas del 6 – 12 de julio y del 23 – 29 de noviembre, de 2020. Esto ilustra el valor de una plataforma actualizable y refleja el impacto de las restricciones de la pandemia en la accesibilidad. Los resultados se obtuvieron en una fracción del tiempo y costo de los estudios tradicionales.

- Se consolidó la identidad del proyecto registrando el logotipo y marca del Proyecto AMORE.
- Diferentes foros consideran que el Proyecto AMORE representa una nueva línea de investigación intersectorial (v.g., OnTime, Google, SdS de Bogotá)

Publicaciones en curso:

- Predicted accessibility improvements for tertiary care emergency services by adding new services, Cali, Colombia, 2020 – Cross-sectional analyses and data modeling using Google API.
- Dynamic Accessibility by Car to Hemodialysis in Cali, Colombia, in 2020: Cross-Sectional Equity Analyses Using Travel-Time Big Data from a Google API
- Dynamic Accessibility by Car to Radiation Therapy Services in Cali, Colombia, in 2020: Cross-Sectional Equity Analyses Using Travel-Time Big Data from a Google API
- Measuring dynamic geographic accessibility with an equity perspective and using publicly available sources: the AMORE Platform. Methodological article.

Potenciales publicaciones

- Predicting improvements in accessibility to radiotherapy services by adding new services. Cali, Colombia, 2020
- Predicting improvements in accessibility to hemodialysis by adding new services. Cali, Colombia, 2020
- Protocolo de la evaluación de uso y valoración de datos

Concursos, becas, y congresos

Agendados

- Seleccionado para presentación oral en Health Systems Global 2022, octubre 31 a noviembre 2, 2022 en Bogotá.
- ICUH 2022 – The 18th International Conference on Urban Health., Valencia, España. Poster presentation. Equitable accessibility to health services using timely measurements. Presenta: Eliana Martínez Herrera <https://isuhconference2022.onsitevents.eu/>

Aplicaciones pendientes de respuesta

- **SOLVE-MIT Novel Measurement Performance Improvement Challenge:** sabremos si somos finalistas con [IQ-Connect](#) el 23 de septiembre.
- XXIV Simposio de Investigaciones en Salud, Universidad del Valle. Presentan Lyda Osorio y Ciro Jaramillo. 19-21 de octubre 2022
- International Forum on Quality & Safety in Healthcare, Copenhagen, 15–17 May 2023.



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Completados

- Online International Seminar "Citizens on the Move: Accessibility and Mobility in the Global South", organized by the Latin American Chapter of the International Network for Transport and Accessibility in Low-Income Communities, IntalInC-LAC. [Simple metrics and timely measurements to advance equitable accessibility to health service](#). Sep 10, 2022.
- GREAT – Gridding equitable Urban Futures in Areas of Transition. Lancaster University, University College London, Universidad del Valle, Universidad Tecnológica de la Habana José Antonio Echeverría. AMORE Project. Guest speaker. 26 July 2022
- II Simposio Internacional de Doctorandos en Desarrollo Urbano Sustentable de Latinoamérica y el Caribe - 2022. Marzo 11, 18 y 15 de 2022.
- Lima Cómo Vamos. Lima Cómo Vamos - Presentación del Proyecto AMORE: Uso de análisis geoespacial dinámico en diálogos de actores clave para mejorar la accesibilidad a los servicios de salud de uso urgente o frecuente, y reducir desigualdades. Prueba de concepto en Cali, Colombia. 4 de noviembre de 2021. Panel con el salubrista Jaimer Miranda, la comunicadoras Mariana Alegre, y Patricia Alata
<https://www.facebook.com/limacomovamos/photos/a.171309686231837/5117762341586522/>
- London School of Hygiene and Tropical Medicine. Guest Speaker, International Diagnostic Centre – Integrated Knowledge Translation and Intersectoral Collaboration in Urban Planning. 26 Nov 2021.
- Global Health Learning Network, University of Ottawa. Seminar on Digital app technology to assess equity: [Spatial analysis and equity for health services](#). Guest speaker. 20 Jan 2022.
- **Participación en eventos relevantes y seguimientos con el director de tesis:**
 - 42 reuniones de seguimiento con los directores de tesis, Profesor Ciro Jaramillo Molina y Profesora Eliana Martínez Herrera, en los últimos 12 meses.
 - Dos reuniones con el Comité de Ética CEMIN, una con un Comité privado en la Universidad SUNY, otro con la Universidad de Ecuador, uno con la Universidad Autónoma de Barcelona.
 - 20 reuniones con el equipo colaborativo del Proyecto AMORE, diferentes participantes entre coautores y desarrolladores de la plataforma.
 - Grabación de video "elevator pitch" del proyecto de < 2 min, IQ-Connect para MIT-SOLVE

Expansión del Grupo Colaborativo AMORE

El grupo es fluido e incluye cerca de 40 aportantes que contribuyen a los diferentes artículos en diferente medida. Aquellos que hacen aportes a los artículos son reconocidos y si aprueban la versión final y envían oportunamente la declaración firmada de conflictos de interés, aparecen listados en el equipo colaborativo. Anexo un ejemplo del equipo preparado para el artículo de análisis de nuevos servicios de urgencias.

Temas a consultar:

- Las potenciales publicaciones exceden el requerimiento
- Apelación de doble titulación; información tardía y limitaciones de internet.
- Menciones internacionales



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En verde, las áreas de desarrollo ofreciendo la comparación y progreso en el último año

Ilustración 1 Situación a septiembre 10 de 2022

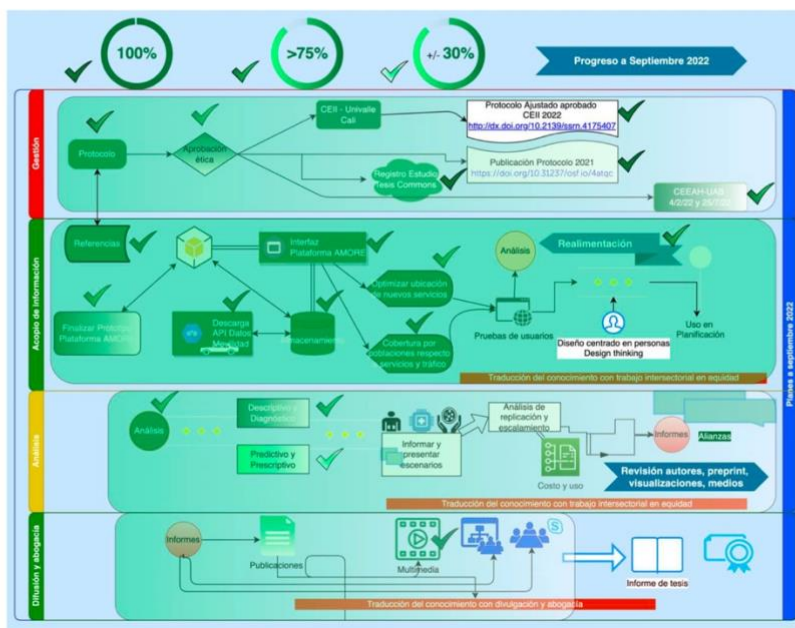
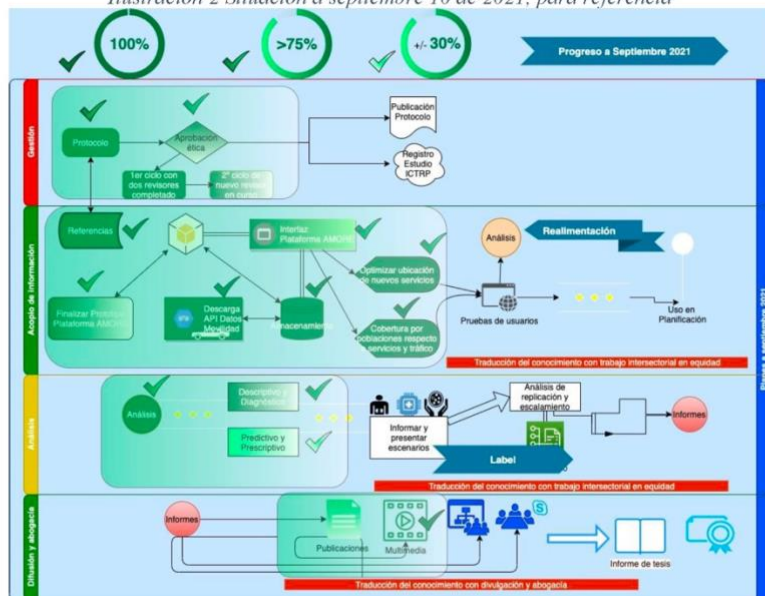


Ilustración 2 Situación a septiembre 10 de 2021, para referencia





Evaluaciones dinámicas de accesibilidad geográfica para mejorar la equidad en salud: prueba en Cali, Colombia. Doctorando: Luis Gabriel Cuervo

PUBLICACIONES

Investigación original

Cuervo LG, Martínez-Herrera E, Osorio L, Hatcher-Roberts J, Cuervo D, Bula MO, Pinilla LF, Piquero F, and Jaramillo D. "Dynamic Accessibility by Car to Tertiary Care Emergency Services in Cali, Colombia, in 2020: Cross-Sectional Equity Analyses Using Travel-Time Big Data from a Google API." *BMJ Open* 12, no. 9 (September 1, 2022): e062178. <https://doi.org/10.1136/bmjopen-2022-062178>. [**>1500** descargas en una semana]

Editorial

Cuervo LG, Martínez-Herrera E, Cuervo D, Jaramillo C. "Improving Equity Using Dynamic Geographic Accessibility Data for Urban Health Services Planning". *Gaceta Sanitaria* (E-Publication ahead of print) 11 Jun 2022. <http://dx.doi.org/10.1016/j.gaceta.2022.05.001>. [1565 descargas]

Preimpresos

Cuervo LG, Jaramillo C, Cuervo D, Martínez Herrera E, Hatcher-Roberts J, Pinilla LF, Bula MO, et al. "Dynamic Geographical Accessibility Assessments to Improve Health Equity: Protocol for a Test Case in Cali, Colombia." SSRN Scholarly Paper. Rochester, NY, July 28, 2022. <https://ssrn.com/abstract=4175407>. <http://dx.doi.org/10.2139/ssrn.4175407>.

Cuervo LG, Cuervo D, Hatcher-Roberts J, Martínez Herrera E, Pinilla LF, Piquero F, Ospina M, and Jaramillo Molina C. "AMORE Project: Integrated Knowledge Translation and Geospatial Analysis to Improve Travel Times to Health Services (Accessibility) and Health Equity in Cali, Colombia: A Proof of Concept Using Mixed-Methods Research." Preprint. Thesis Commons, November 19, 2021. <https://doi.org/10.31237/osf.io/4atqc>.

Cuervo LG, Martínez-Herrera E, Osorio L, Hatcher-Roberts J, Cuervo D, Bula MO, Pinilla LF, Piquero F, Jaramillo C. Cross-sectional equity analysis of accessibility by automobile to tertiary care emergency services in Cali, Colombia in 2020. medRxiv 2022.02.03.22269929; doi: <https://doi.org/10.1101/2022.02.03.22269929>

Multimedia y gráficos

Cuervo LG, Villamizar CJ, Martínez-Herrera, E, Zapata P, Jaramillo C. (2022): Impact of traffic build-up on accessibility to tertiary care emergency services in Cali, Colombia, 6 - 12 July 2020. figshare. Media. <https://doi.org/10.6084/m9.figshare.21076726>

Cuervo LG, Villamizar CJ, Jaramillo C, Martínez-Herrera, E; Cuervo D. (2022): Theory of Change for AMORE Project Protocol 2022. figshare. Figure. <https://doi.org/10.6084/m9.figshare.20485404.v2>

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2.18.4 2023



Evaluaciones dinámicas de accesibilidad geográfica para mejorar la equidad en salud: prueba en Cali, Colombia. Doctorando: Luis Gabriel Cuervo • 11 de septiembre de 2023

Portada: Luis Gabriel CUERVO (Doctorando, Líder del Proyecto AMORE)

Supervisión: Ciro JARAMILLO MOLINA (director de tesis), Eliana MARTÍNEZ HERRERA (directora de tesis), Xavier BONFILL i COSP (tutor).

Portal y listado de colaboradores: https://padlet.com/Proyecto_AMORE_Project/products

Página [LinkedIn](#) y [Visión 2023 \(6'30'' en español\)](#)

Desarrollos del 11 de septiembre 2022 a 10 de septiembre de 2023

El proyecto se desarrolla según lo previsto para su producción y validación científica, así como en influir el debate de la política pública relevante. En el último año ha habido participación por concurso e invitación en foros internacionales y locales (salud, movilidad, urbanismo, demografía, política pública, e investigación en servicios y sistemas de salud). La OMS y expertos de OPS/OMS están valorando adoptar métricas de accesibilidad sensibles al tráfico de ciudades congestionadas.

El proyecto se ha vinculado en observatorios y escenarios de participación ciudadana y proyectos del City Cancer Challenge y la Asociación Colombiana de Deportistas Trasplantados.

Este año se publicó [el protocolo](#) (Q1, 580 visitas) y un [preimpreso](#) del informe del análisis situacional y predicciones de accesibilidad a los servicios de hemodiálisis para Cali resultantes de agregar servicios en ubicaciones estratégicas. Este incluye datos desagregados que ofrecen una perspectiva de equidad. Este último manuscrito está bajo revisión en The Lancet Regional Health Americas (Q1). Estamos preparando el manuscrito del análisis situacional y predicciones el estudio de caso de radioterapia (Anexo C). Esto se complementa con la publicación de materiales complementarios en [Figshare](#), [Thesis Commons](#), YouTube (71 videos el último año) y [Open Science Framework](#) (incluyendo bases de datos).

Mi doctorado inició en febrero de 2020. La recolección de datos está completa y las publicaciones van encaminadas a satisfacer con creces el requerimiento para graduación; previamente, se publicó una [editorial](#) en Gaceta Sanitaria (Q3, >3800 visitas) exponiendo el tema, retos y oportunidades y los resultados en [BMJ Open](#) (Q1, >4650 accesos) del análisis situacional de la accesibilidad a los servicios de urgencias de alta complejidad.

El problema que aborda el proyecto es la imposibilidad de planificar los servicios de salud con datos que consideren la congestión del tráfico y la equidad en salud, en ciudades congestionadas. Los estudios existentes no consideran el tráfico ni la equidad, son onerosos y se presentan en formatos sofisticados, que solo especialistas entienden, limitando el impacto en la política pública y participación ciudadana. En consecuencia, la congestión del tráfico:

- Retrasa los servicios de salud de emergencia.
- Impacta desproporcionadamente en los usuarios regulares de los servicios de salud, causando tensiones financieras y gastos catastróficos.
- Puede tener un impacto desproporcionado en las poblaciones pobres y marginadas.
- No puede atenderse en forma participativa y coordinada.

Utilizando una estrategia construcción colectiva e investigación participativa centrada en poblaciones, desarrollamos una propuesta de bajo costo (sin financiación externa) para que las ciudades aprovechen datos abiertos y midan con precisión la accesibilidad a servicios de salud considerando la congestión del tráfico. Incorporamos buenas prácticas de punta presentando datos desagregados que brindan una perspectiva de equidad. Identificamos el efecto del tráfico en las poblaciones y aportamos predicciones y opciones para optimizar la accesibilidad apuntando a ubicaciones idóneas para nuevos servicios. Impulsamos la apropiación social con:

- Estadísticas descriptivas y cartografía que la mayoría de las gentes pueden interpretar.



Evaluaciones dinámicas de accesibilidad geográfica para mejorar la equidad en salud: prueba en Cali, Colombia. Doctorando: Luis Gabriel Cuervo • 11 de septiembre de 2023

- Colaboración con las partes interesadas, incluidos los proveedores de servicios de salud, los usuarios, las autoridades y los analistas de datos.
- Proponiendo configuraciones y adaptaciones para integrar otros datos, escalar el proyecto, y aplicarlo al monitoreo y planificación basados en datos.

Este vídeo en inglés, con subtítulos traducidos automáticamente al español, describe el proyecto en menos de un minuto: <http://tinyurl.com/1-min-AMOREProject>. En el último año ha habido creciente interés de la sociedad civil, las autoridades y usuarios de los datos.

Consolidación del equipo colaborativo

El perfil de más de tres docenas personas vinculadas al Proyecto Colaborativo AMORE se puede encontrar [pinchando la imagen o este enlace](#). Estos actores clave han aportado al proyecto y revisado las publicaciones declarando conflictos de interés y aportes.

Siguiendo el modelo propuesto por (Abimbola, 2020) y promotores de la participación comunitaria (Jull et al., 2019; Rifkin, 2012), de usuarios de los datos y programadores (Papa et al., 2017; Whitty, 2015), participan autoridades locales, nacionales e internacionales (gobernanza constitucional); académicos y representantes de la sociedad civil organizada (gobernanza colectiva); usuarios y prestadores de servicios (gobernanza operativa).



Las hipótesis y preguntas de investigación se exponen en el protocolo (Cuervo et al., 2022). Paralelamente se ha contribuido al desarrollo de estándares para informar equidad en estudios observacionales (Dewidar et al., 2022; Funnell et al., 2023; Petkovic et al., 2020; Tugwell et al., 2020).

Comunicación y apropiación social del conocimiento

El proyecto colaborativo ha logrado insertarse en el debate de política pública sobre planificación urbana y de servicios de salud en la ciudad de Cali y en Bogotá, dos ciudades que están entre las más congestionadas de Latinoamérica. La [página LinkedIn del proyecto](#) cuenta con más de seiscientos seguidores.



Evaluaciones dinámicas de accesibilidad geográfica para mejorar la equidad en salud: prueba en Cali, Colombia. Doctorando: Luis Gabriel Cuervo • 11 de septiembre de 2023

Para destacar

Perspectivas de usuarios en el LEAD Innovation Challenge de OMS

Entrevistas semiestructuradas con cuatro usuarios, quienes aportaron reflexiones y valoración del Proyecto AMORE en la política pública y planificación de servicios de salud. Estos expertos fueron:

- **Gloria Stefanny Ortiz Gómez:** Comunicadora social del observatorio urbano Cali Cómo Vamos
- **Pablo Javier Patiño Grajales:** integrante de la Misión Internacional de Sabios de Colombia, profesor titular de la Facultad Nacional de Salud Pública y aspirante a la decanatura.
- **Iliana F. Curiel Arismendy:** directora de Salud Colectiva de la Secretaría de Salud de Bogotá
- **Sara Marcela Valencia Cadavid:** PhD en estudios de ciencia y tecnología, exdirectora del Centro Distrital de Educación e Investigación en Salud de Bogotá, gerente de monitoreo y evaluación en aprendizaje y colaboración de ABT Colombia para USAID.

Observatorio urbano Cali Cómo Vamos

Además de las notas destacadas por el observatorio ciudadano, las entrevistas con OMS generaron el interés de incorporar los datos del Proyecto AMORE al observatorio ciudadano y se está gestionando la inclusión de un enlace a la Plataforma AMORE en Datos que hacen ciudad, en Informes especiales, y generar más [aportes al blog ciudadano](#).

City Cancer Challenge Foundation

Fui invitado a una entrevista con la directora regional para Latinoamérica y el director mundial de innovación y financiación de City Cancer Challenge el 30 de mayo, en la cual expresaron interés en colaborar con el Proyecto AMORE para avanzar el pilar de entrega de servicios de salud. Mencionaron que buscarían informar a su socio, ProPacífico, con quien implementan un proyecto en Colombia. Tenemos planificado un encuentro en Washington DC a mediados de septiembre de 2023.

Propacífico

Esta fundación privada sin ánimo de lucro es líder influyente en Cali y el departamento de Valle del Cauca impulsando proyectos e iniciativas de alto impacto. Además, hace seguimiento al cumplimiento de las administraciones locales. Propacífico coordina el proyecto local de City Cancer Challenge Foundation y los debates ciudadanos con los candidatos a la alcaldía de Cali. Luego de la reunión con el equipo de cáncer, determinaron que el Proyecto AMORE aportará información valiosa para los debates ciudadanos y un abordaje más holístico de la planificación y monitoreo de servicios, y elevaron el tema con la directora de la fundación, y el director del proyecto de salud, con quienes hemos tenido intercambios semanales desde agosto de 2023. Por ejemplo, nos han solicitado aportar preguntas relevantes al uso del abordaje y datos, para los debates con candidatos a la alcaldía de Cali respecto a movilidad (17 de agosto, Universidad San Buenaventura), planeación (31 de agosto, Universidad del Valle), y salud (28 de septiembre, Pontificia Universidad Javeriana).

JHU-UPF Public Policy Center

La maestranda en salud pública del centro Johns Hopkins University – Universitat Pompeu Fabra de política pública, Lic. Carmen Juliana Villamizar, construyó sobre el Proyecto AMORE un análisis sobre el abordaje propuesto en la toma de decisiones en la planificación de servicios, entrevistando actores clave. Este constituyó su [trabajo final para la maestría en salud pública en la Escuela de Salud Pública Bloomberg de la Universidad John's Hopkins](#), obteniendo su grado en mayo de 2023. Está en curso la publicación del trabajo final y un artículo liderado por la graduada (Villamizar Jaimes, 2023).



Evaluaciones dinámicas de accesibilidad geográfica para mejorar la equidad en salud: prueba en Cali, Colombia. Doctorando: Luis Gabriel Cuervo • 11 de septiembre de 2023

Presentaciones y eventos por concurso e invitación:

World Health Organization - LEAD Innovation Challenge 2023 (Lead Engage Accelerate Disrupt)

El concurso [LEAD Innovation Challenge](#) de OMS por primera vez incluyó la OPS/OMS, oficina regional para las Américas. En el mes previo al 21 de marzo se recibieron ejemplos de demandas de innovaciones e incluyó la demanda de datos dinámicos de accesibilidad a servicios de salud. Se sometieron 53 ideas sobre cómo atender las demandas, con plazo 24 de abril, incluyendo Driving Towards Equity, que representa la expansión del Proyecto AMORE. Para el 23 de mayo los proyectos debían proponer un equipo de personas de OMS que lo apoyara y presentar ante un jurado internacional de OMS que seleccionó diez finalistas. Habiendo sido seleccionados, participamos entre mayo y agosto en talleres intensivos de capacitación seleccionó *Driving Towards Equity* como finalista. Participamos en presentaciones y talleres, incluyendo un taller intensivo de una semana, con tres horas diarias de orientación seguidas de trabajo del equipo, para completar la fase de validación del proyecto en agosto. Cinco proyectos fueron seleccionados para recibir hasta 50,000 USD de OMS; no recibimos el emolumento, pero sí una felicitación del jurado y la invitación a continuar con la cohorte de OMS promoviendo la adopción de métricas con datos dinámicos de accesibilidad.

Presentación al panel de OMS y síntesis del proyecto incluyendo una [nota de un minuto](#).

International Forum on Quality and Safety in Healthcare, Copenhagen 2023.

Session L1: A dynamic, interactive platform for assessing urban health services' accessibility and equity. Tuesday, May 16, 2023. 12:30 to 13:00. Bella Center, Copenhagen, Auditorium C1M3. Organized by the Institute of Healthcare Improvement and BMJ. Presented by Luis Gabriel Cuervo on behalf of the AMORE Collaborative Project, Doctoral student, Universitat Autònoma de Barcelona. Conference contribution. <https://doi.org/10.6084/m9.figshare.23026166.v1>

Available from <https://internationalforum.bmj.com/handouts-copenhagen-2023/> Handouts: <https://internationalforum.bmj.com/copenhagen/wp-content/uploads/sites/18/2023/05/20230509-Infographic-2-and-maps-haemodialysis-July-2020.pdf>

III Simposio de Gestión de datos: ciudades inteligentes

Medición de accesibilidad espacial a servicios prioritarios de salud, una perspectiva de equidad territorial partiendo de datos públicamente disponibles. Presenta Ciro Jaramillo Molina, en representación del Proyecto AMORE. 16 de agosto de 2023. Escuela Colombiana de Ingeniería Julio Garavito en colaboración con Data Management Colombia Chapter y la Asociación Colombiana de Ingenieros de Sistemas.

Population Reference Bureau (PRB) -Webinar: Big data analysis on a Shoestring. Using publicly available data for population and global health research.

Study 1: Can Google Data help measure health care access more accurately? Presentation by Luis Gabriel Cuervo on behalf of the AMORE Collaborative Project. March 27, 2023. Moderators Toshiko Kaneda and Lori S. Ashford. Website: Analyzing Big Data on a Shoestring Budget. <https://youtu.be/UwG6XivJWZo>

III Simposio Internacional de Doctorandos en Desarrollo Urbano Sustentable de Latinoamérica y el Caribe.

Mediciones de accesibilidad a servicios de salud y predicciones de impacto agregando nuevos servicios: una perspectiva de equidad partiendo de datos públicamente disponibles. Área 3: Accesibilidad y movilidad. Marzo de 2023. <https://redeus.org/luis-gabriel-cuervo/>

Seminario de la Escuela de Gobierno y Transformación Pública - Tecnológico de Monterrey.

Midiendo la accesibilidad urbana a los servicios de salud con perspectiva de equidad. Seminario IPPS (Iniciativa de Política Pública y Salud). Ciudad de México: Escuela de Gobierno y Transformación Pública, TEC de Monterrey, 7 de febrero de 2023.



Evaluaciones dinámicas de accesibilidad geográfica para mejorar la equidad en salud: prueba en Cali, Colombia. Doctorando: Luis Gabriel Cuervo • 11 de septiembre de 2023

Congreso Internacional del Modelo Territorial de Salud, Bogotá, 2022.

Accesibilidad a los servicios de salud con una perspectiva de equidad. 24 de noviembre de 2022.

Evaluaciones Dinámicas Con Datos Públicamente Disponibles. Bogotá DC: Secretaría Distrital de Salud de Bogotá, 24 de noviembre de 2022. <https://doi.org/10.6084/m9.figshare.21565614.v2>

Seventh Global Symposium on Health Systems Research, Bogotá 2022.

Invitación por concurso y becado: Cuervo LG. Assuring Access to Health Care for All: A New Approach to Assess Equity in Accessibility to Health Services." Hybrid Oral Session on Comprehensive Primary Care in Promoting Sustainability: presented at the Seventh. Global Symposium on Health Systems Research. Ágora Conference Center, Bogotá DC., 2 de noviembre de 2022.

International Society for Urban Health, Valencia 2022.

Martínez-Herrera, Eliana, Luis Gabriel Cuervo, Carmen Juliana Villamizar, Daniel Cuervo, and Ciro Jaramillo Molina. "Equitable Accessibility to Health Services Using Timely Measurements." In *International Society for Urban Health*. Valencia, Spain: International Society for Urban Health., Oct 24-27, 2022. <https://doi.org/10.6084/m9.figshare.21375750.v1>

XXIV Simposio Nacional e Internacional de Investigaciones en Salud: Consecuencias de la pandemia: una mirada global.

Jaramillo Molina C, Osorio L, Cuervo LG, Villamizar CJ. "Mejorando la equidad en la accesibilidad (tiempos de viaje) a los servicios de salud.", Cali, Colombia, October 21, 2022.

Presentaciones sucedáneas

Academia Nacional de Medicina

En mi ceremonia de inducción a la Academia Nacional de Medicina el 3 de noviembre de 2022, el académico [Dr. Juan Manuel Anaya Cabrera](#), coordinador del Foco de Ciencias de la Vida y la Salud de la Misión Internacional de Sabios de Colombia, [destacó el Proyecto AMORE](#), sus objetivos y alcances, como una "una elegante y útil prueba de concepto para mejorar la equidad en salud reduciendo los tiempos de viaje a los servicios mediante la colaboración intersectorial".

Global Health Program for Fellows and Scholars /Launching Future Leaders in Global Health Research Training Program (LAUNCH)

El Centro Internacional Fogarty de los Institutos Nacionales de Estados Unidos pidió una presentación para inspirar a los más de cien nuevos becarios de cuarenta países a involucrarse en proyectos de creación colectiva y apropiación social del conocimiento con actores clave de las comunidades, y se utilizó el Proyecto AMORE para ilustrar los elementos que querían destacar.

UKRI-GCRF Gridding Equitable Urban Futures in Areas of Transition GREAT.

Consortios liderados en el Reino Unido por la Universidad de Lancaster y la Bartlett/Development Planning Unit, UCL; en Colombia por la Universidad del Valle; y, en Cuba, por la Universidad Tecnológica de La Habana. Después de la presentación de julio de 2022, nos hemos mantenido en contacto, dos investigadores se unieron al Proyecto AMORE y se nos otorgaron los derechos para usar un [video producido por Populab](#) ilustrando la situación que enfrentan los pacientes para trasladarse a tratamientos de cáncer y hemodiálisis desde la periferia de Cali.

FIN



ANEXO A - REFERENCIAS

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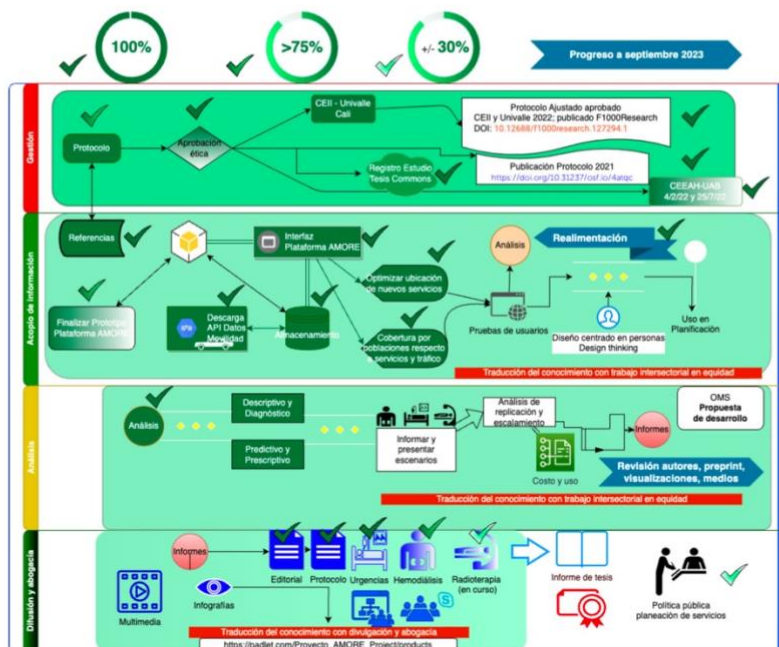
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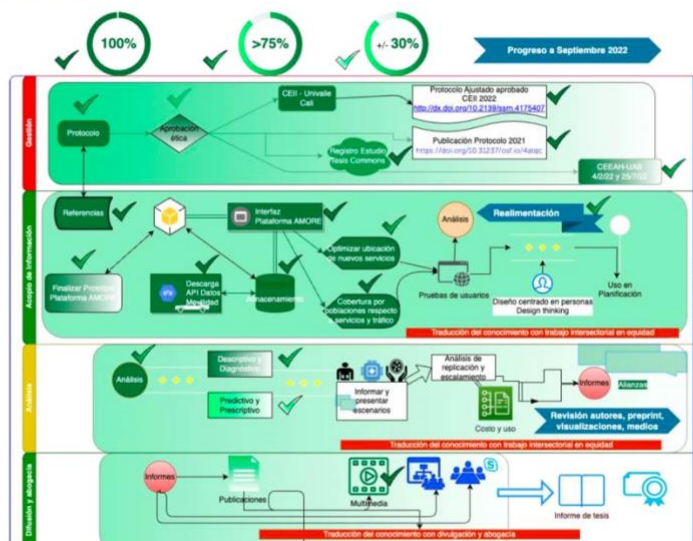
Evaluaciones dinámicas de accesibilidad geográfica para mejorar la equidad en salud:
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ANEXO B – Gráfico de progreso

1 - Informe de progreso 2023



2 - Informe de progreso 2022





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ANEXO C – Histórico y proyección para modalidad de grado por publicaciones

Referencia: https://padlet.com/Proyecto_AMORE_Project/products

Estado actual y desarrollo futuro de cada uno de los artículos que componen la tesis según el semestre de cada año (Fuente: Semestre Preimpreso Publicación)		
2021-1		
2021-2	"AMORE Project: Integrated Knowledge Translation and Geospatial Analysis to Improve Travel Times to Health Services (Accessibility) and Health Equity in Cali, Colombia: A Proof of Concept Using Mixed-Methods Research." Preprint. Thesis Commons, November 19, 2021. https://doi.org/10.31237/osf.io/4atqc	
2022-1	Cuervo, Luis Gabriel, Eliana Martínez Herrera, Lyda Osorio, Janet Hatcher Roberts, Daniel Cuervo, María Olga Bula, Luis Fernando Pinilla, Felipe Piquero, Ciro Jaramillo, and the AMORE Project Collaboration. "Cross-Sectional Equity Analysis of Accessibility by Automobile to Tertiary Care Emergency Services in Cali, Colombia in 2020." medRxiv, February 4, 2022. https://doi.org/10.1101/2022.02.03.22269929 .	
2022-2	Cuervo LG, Jaramillo C, Cuervo D, Martínez Herrera E, Hatcher-Roberts J, Pinilla LF, Bula MO, Osorio L, Zapata Murillo P, Piquero Villegas F, Ospina MB, Villamizar Jaimés CJ. Dynamic Geographical Accessibility Assessments to Improve Health Equity: Protocol for a Test Case in Cali, Colombia (July 28, 2022) F1000Research, November 28, 2022. https://doi.org/10.12688/f1000research.127294.1 Cuervo LG, Jaramillo C, Cuervo D et al. Dynamic geographical accessibility assessments to improve health equity: protocol for a test case in Cali, Colombia [version 1; peer review: 1 approved]. F1000Research 2022, 11:1394 (https://doi.org/10.12688/f1000research.127294.1 , Available at SSRN: https://ssrn.com/abstract=4175407 or http://dx.doi.org/10.2139/ssrn.4175407	Cuervo LG, Martínez-Herrera E, Cuervo D, Jaramillo C. "Improving equity using dynamic geographic accessibility data for urban health services planning." Gaceta Sanitaria 36, no. 6 (November 1, 2022): 497–99. https://doi.org/10.1016/j.gaceta.2022.05.001 Cuervo LG, Jaramillo C, Cuervo D et al. Dynamic geographical accessibility assessments to improve health equity: protocol for a test case in Cali, Colombia [version 1; peer review: 1 approved]. F1000Research 2022, 11:1394 (https://doi.org/10.12688/f1000research.127294.1 Cuervo LG, Martínez-Herrera E, Osorio L, et al. "Dynamic Accessibility by Car to Tertiary Care Emergency Services in Cali, Colombia, in 2020: Cross-Sectional Equity Analyses Using Travel-Time Big Data from a Google API." BMJ Open 12, no. 9 (September 1, 2022): e062178. https://doi.org/10.1136/bmjopen-2022-062178 .
2023-1	Cuervo LG, Villamizar CJ, Osorio L, Ospina MB, Cuervo DE, Cuervo D, Bula MO, Zapata P, Owens NJ, Hatcher-Roberts J, Martin EA, Piquero F, Pinilla LF, Martínez-Herrera E, Jaramillo C. Cross-Sectional Equity Analysis of Accessibility by Automobile to Haemodialysis Services in Cali, Colombia, in 2020 (December 9, 2022). Available at SSRN: https://ssrn.com/abstract=4299562	
2023-2	Planificada: Cross-Sectional Equity Analysis of Accessibility by Automobile to Radiation Therapy Services in Cali, Colombia, in 2020 Use of dynamic geographical accessibility measurements in public policy: case study for Cali, Colombia	Cuervo LG, Villamizar CJ, Osorio L, Ospina MB, Cuervo DE, Cuervo D, Bula MO, Zapata P, Owens NJ, Hatcher-Roberts J, Martin EA, Piquero F, Pinilla LF, Martínez-Herrera E, Jaramillo C. "Dynamic measurements of geographical accessibility considering traffic congestion using open data: cross-sectional assessment for haemodialysis services in Cali, Colombia" . [En proceso de revisión por pares, The Lancet Regional Health Americas (Q1)]
2024-1	Development of a research line in dynamic accessibility measurements for health services that integrates travel time big data with open data of populations and services	

2.18.5 2024



Evaluaciones dinámicas de accesibilidad geográfica para mejorar la equidad en salud: prueba en Cali, Colombia. Doctorando: Luis Gabriel Cuervo • 10 de septiembre de 2024

Doctorando: Luis Gabriel CUERVO (Doctorando, Líder del Proyecto AMORE). Supervisión: Ciro JARAMILLO MOLINA (director de tesis), Eliana MARTÍNEZ HERRERA (directora de tesis), Xavier BONFILL i COSP (tutor).

Portal y listado de colaboradores: https://padlet.com/Proyecto_AMORE_Project/products

Progresos desarrollo de tesis (10 de septiembre 2023 al 10 de septiembre de 2024)

El trabajo doctoral avanza y estimamos cumplir los requisitos para proceder a preparar el documento de tesis doctoral por compendio de publicaciones, necesario para el depósito de tesis.

Publicaciones doctorando Luis Gabriel Cuervo

DOI	ISO Revista	Año Cuartil JCR/Scimago	Factor de Impacto	JCI	Percentil	Orden/Autores	Corresponsal
10.1186/s12939-024-02211-6	Int. J Equity Health	2023 Q1 / Q1	4,5 / 4,3	1,2	90	1/21	Si
10.26633/RPSP.2024.69	Rev. Panam. Salud Publica	2023 Q3 / Q2	2,0 / 2,0	0,5	46,8	2/6	No
10.1016/j.lana.2024.100752	Lancet Regional Health-Americas	2023 Q1 / Q1	7,0 / 6,8	2,93	98	1/15	Si
10.1136/bmjopen-2022-062178	BMJ Open	2022 Q1 / Q1	2,9 / 2,8	0,72	76	1/9	Si
10.12688/11000research.127294.1	F1000Research	2022 NA / Q1				1/12	Si
10.1016/j.gaceta.2022.05.001	Gac Sanit	2022 Q3 / Q3	1,9 / 1,8	0,63	26,4	1/4	Si

En nuestras publicaciones, proponemos y probamos una metodología de investigación participativa destinada a informar la política pública intersectorial en determinantes sociales de la salud. Esta metodología integra aspectos de apropiación social y traducción integrada del conocimiento, con un enfoque en la equidad y la justicia social. Las dos publicaciones de 2024 en revistas Q1 fueron destacadas como favoritas de los editores.^{1,2}

Recientemente se han publicado varias evaluaciones dinámicas de accesibilidad. Nuestro enfoque pionero se distingue por estar desarrollado por un equipo diverso de personas que moldean la planificación urbana y de servicios, con un enfoque centrado en las poblaciones, una perspectiva de equidad, y basándose en datos abiertos y macrodatos. Esto hace que sea eficiente y útil tanto para el monitoreo como para el desarrollo, facilitando su replicación, adaptación y escalamiento. Seguimos buenas prácticas en el desarrollo y transferencia de conocimiento, involucrando a científicos de datos y usuarios en cada etapa del proceso: desde la conceptualización y el desarrollo, hasta la implementación y la elaboración de informes. Una implementación novedosa de nuestro enfoque ya ha sido emulada por otros. Publicamos las interfaces de nuestra plataforma interactiva en la web, permitiendo que los datos hablen por sí mismos y brindando a los lectores la oportunidad de probar escenarios y enriquecer las discusiones con sus propios datos.

El grupo colaborativo del Proyecto de Análisis con Macrodatos para Orientar Resultados en Equidad (AMORE) está compuesto por medio centenar de voluntarios, de las cuales la mitad han sido coautores de publicaciones. Varias de estas personas han presentado el proyecto en eventos convocados por diferentes sectores, todas han contribuido al estudio, y algunas han obtenido testimonios o materiales que amplían el contexto del estudio, los cuales se pueden consultar en el [Padlet™](#) del proyecto.

Desarrollos de la línea de investigación vinculados al proyecto

Algunos integrantes entraron al estudio con interés de ampliar la línea de investigación que hemos desarrollado. Nuestra administradora, la terapeuta [Carmen J. Villamizar](#) es licenciada en administración y recientemente completó su maestría en salud pública. En su tesis evaluó la plataforma digital interactiva del proyecto AMORE desde la perspectiva de quienes moldean la planificación urbana y de servicios. Estas entrevistas formaron parte de su maestría en salud pública en la Escuela Bloomberg de Salud



Evaluaciones dinámicas de accesibilidad geográfica para mejorar la equidad en salud: prueba en Cali, Colombia. Doctorando: Luis Gabriel Cuervo • 10 de septiembre de 2024

Pública de la Universidad Johns Hopkins, durante su estancia como visitante en el Centro de Política Pública JHU-UPF.

Por otro lado, la profesora [Carol Viviana Paredes](#), médica especialista en medicina familiar, realiza su proyecto de grado de maestría en salud pública en la Universidad del Valle. Su estudio compara los resultados descriptivos y gráficos del Proyecto AMORE con indicadores tradicionales de desigualdad basados en áreas bajo la curva, que, aunque son ampliamente usados en economía, presentan dificultades para su aplicación en trabajos intersectoriales y participativos.

El profesor [Jorge Gallego Méndez](#), ingeniero topográfico y especialista en geomática, está utilizando los datos de nuestro estudio para explorar nuevas aplicaciones en el ordenamiento territorial y la planificación de servicios.

En junio de 2024 se vinculó al proyecto la maestranda en comunicación científica Lic. [Laura V. Molina Benavides](#), comunicadora de la Secretaría Distrital de Salud de Bogotá, para aportar al proyecto desde su rol de maestranda en Comunicación Social de la Investigación Científica de la Universidad Internacional de Valencia. Con ella se solidificó un plan de comunicación y apropiación social del conocimiento, al cual han contribuido varios integrantes del equipo colaborador y los directores de tesis. Se han publicado materiales en [Figshare](#), [Thesis Commons](#), YouTube (49 vídeos el último año) y [Open Science Framework](#) (incluyendo los datos crudos).

Si la emulación es un elogio, este año recibimos uno grande pues encontramos nuestras ideas siendo replicadas y adaptadas en Nigeria, por parte de un grupo de autores que nos contactó por intermedio de Google en 2020 para aprender cómo habíamos logrado hacer el estudio sin financiación, y cómo estábamos facilitando la transferencia del conocimiento. Publicaron su informe en The Lancet Global Health incluyendo una plataforma interactiva virtual, si bien no indicaron los sitios idóneos para nuevos servicios.

Difusión, apropiación y aplicación de nuestra investigación en la gestión urbana

Este año consolidamos alianzas estratégicas para la implementación de los resultados y la adopción de esta metodología de investigación en salud pública. Entre ellas destacamos la fundación internacional [City Cancer Challenge – C/Can](#) que trabaja en Cali con la fundación [ProPacífico](#), así como la red Ciudades Cómo Vamos, que incluye el observatorio ciudadano [Cali Cómo Vamos](#), promotores activos de la divulgación de nuestros hallazgos. Estas instituciones apoyan la gestión municipal y promueven la rendición de cuentas de la administración pública. Las directoras ejecutivas de C/Can y ProPacífico, junto con sus equipos técnicos y de comunicación, han colaborado en la divulgación y promoción de las recomendaciones del estudio.

La Universidad del Valle convocó un seminario el 18 de septiembre para debatir sobre el ordenamiento territorial municipal, considerando los hallazgos y oportunidades de nuestra metodología de investigación y su prueba de concepto local. Se espera que el evento culmine con recomendaciones dirigidas a la alcaldía y el concejo municipal, basadas en los hallazgos del proyecto de doctorado y en la participación de autoridades, prestadores de servicios, representantes de pacientes y organizaciones cívicas. ProPacífico y Univalle han invitado autoridades de salud, movilidad, ciudad inteligente y planeación, actores cívicos, proveedores de servicios, e investigadores.

Los integrantes del equipo colaborativo continúan participando en eventos pertinentes, en foros internacionales y locales, en temas de salud, movilidad, urbanismo, demografía, política pública e investigación en servicios y sistemas de salud. La Organización Panamericana de la Salud concursó y fue finalista con este proyecto doctoral en el LEAD Innovation Challenge 2023 de la Organización Mundial de



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la Salud (OMS), liderados por el doctorando. El doctorando y los participantes vinculados a OPS/OMS recibieron certificación y reconocimiento por parte del director de la OMS.

El coordinador de emergencias de OPS/OMS invitó al director de tesis a presentar la metodología en un panel regional de coordinadores de preparación y respuesta a emergencias, en octubre 2024, en Quito.

Siguiendo recomendaciones para vincular la investigación a la política pública y el protocolo, las interfaces de cada estudio de caso están públicamente disponibles permitiendo que las partes interesadas prueben escenarios, y se expongan a datos e imágenes que comunican los resultados del estudio. Estas están en <<https://www.iqartil.net/proyectoAMORE/>>. ^{3,4}

Difusión de las publicaciones

La influencia y divulgación del estudio doctoral sigue aumentando con miles de descargas de las publicaciones. El Padlet™ y las publicaciones Q1 de 2024 ofrecen perspectivas actores clave, como pacientes, líderes cívicos y empresarios.

Descargas a 31 de agosto de 2024.

Tema	DOI	Revista	Publicado	Preprint +Publicación
Radioterapia	10.1186/s12939-024-02211-6	Int. J Equity Health.	15-08-2024	736+839 1,575
Evaluación decisores	10.26633/RPSP.2024.69	Rev. Panam. Salud Publica.	14-08-2024	NA +374 374
Hemodiálisis	10.1016/j.lana.2024.100752	Lancet Regional Health-Americas.	03-05-2024	741 +NA
Emergencias de alta complejidad	10.1136/bmjopen-2022-062178	BMJ Open.	01-09-2022	2396+10060 12,456
Protocolo	10.12688/f1000research.127294.1	F1000Research.	28-11-2022	NA+984 984
Editorial	10.1016/j.gaceta.2022.05.001	Gac Sanit.	11-06-2022	NA+5501 5,501

Nuestras publicaciones ya han sido citadas en una decena de artículos en revistas de distintos sectores, disciplinas y continentes. Entre estas están:

- Wei, Xiaoxuan, Liyin Shen, Xiaoyun Du, Zhenchuan Yang, Zhenhua Guo, and Qiaorong Yin. "How Can Multi-Source Heterogeneous Data Contribute to Assessing Urban Transportation Carrying Capacity?" *Environmental Impact Assessment Review* 108 (September 1, 2024): 107602. <https://doi.org/10.1016/j.eiar.2024.107602>
- Wang, F., and Y. Wang. "How Geographic Accessibility and Rural Governance Mitigate the Impact of Multiple Risks on Rural Households' Well-Being: Evidence from the Dabie Mountains in China." *Journal of Geographical Sciences* 34, no. 6 (2024): 1195–1227. <https://doi.org/10.1007/s11442-024-2245-8>.
- Macharia, Peter M., Kerry L. M. Wong, Lenka Beňová, Jia Wang, Prestige Tatenda Makanga, Nicolas Ray, and Aduragbemi Banke-Thomas. "Measuring Geographic Access to Emergency Obstetric Care: A Comparison of Travel Time Estimates Modelled Using Google Maps Directions API and AccessMod in Three Nigerian Conurbations." *Geospatial Health* 19, no. 1 (May 27, 2024). <https://doi.org/10.4081/gh.2024.1266>.
- Banke-Thomas, Aduragbemi, Kerry L. M. Wong, Tope Olubodun, Peter M. Macharia, Narayanan Sundararajan, Yash Shah, Gautam Prasad, et al. "Geographical Accessibility to Functional Emergency Obstetric Care Facilities in Urban Nigeria Using Closer-to-Reality Travel Time



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Estimates: A Population-Based Spatial Analysis. *The Lancet Global Health* 12, no. 5 (May 1, 2024): e848–58. [https://doi.org/10.1016/S2214-109X\(24\)00045-7](https://doi.org/10.1016/S2214-109X(24)00045-7).

- Wang, J., Wong, K.L.M., Olubodun, T. *et al.* **Developing policy-ready digital dashboards of geospatial access to emergency obstetric care: a survey of policymakers and researchers in sub-Saharan Africa.** *Health Technol.* 14, 69–80 (2024). <https://doi.org/10.1007/s12553-023-00793-9>
- Funnell, S., J. Jull, L. Mbuagbaw, V. Welch, O. Dewidar, X. Wang, M. Lesperance, et al. **“Improving Social Justice in Observational Studies: Protocol for the Development of a Global and Indigenous STROBE-Equity Reporting Guideline.”** *International Journal for Equity in Health* 22, no. 1 (2023). <https://doi.org/10.1186/s12939-023-01854-1>.
- Macharia, Peter M., Kerry L. M. Wong, Tope Olubodun, Lenka Beňová, Charlotte Stanton, Narayanan Sundararajan, Yash Shah, et al. **“A Geospatial Database of Close-to-Reality Travel Times to Obstetric Emergency Care in 15 Nigerian Conurbations.”** *Scientific Data* 10 (October 23, 2023): 736. <https://doi.org/10.1038/s41597-023-02651-9>.
- Murillo-Hoyos J, García-Moreno LM, Tinjacá N, Jaramillo C. Mortalidad por lesiones de tránsito y desigualdades sociales en Colombia, 2019 [Deaths from traffic injuries and social inequality in Colombia, 2019 / Mortalidade por acidentes de trânsito e desigualdades sociais na Colômbia, 2019]. *Rev Panam Salud Publica.* 2023 Aug 31;47:e121. Spanish. doi: 10.26633/RPSP.2023.121. PMID: 37654795; PMCID: PMC10464641.
- Miao, Y., Dai, T., & Song, J. (2023). **Assessing the effects of the large-scale road construction on the ethnic disparities of accessibility in Tibet from 2010 to 2020.** *Growth and Change*, 54(3), 754-770. <https://doi.org/10.1111/grow.12668>

Oportunidades emergentes para publicación relevante

El 9/9/2024 el IJFH (Q1) informó que fuimos seleccionados para someter a noviembre un manuscrito al número especial “Progress in Reducing Inequalities in Health-Related SDGs in the *PostPandemic*”.

Publicaciones pendientes de decisión editorial:

- Estudio de caso aplicando el **enfoque estratégico de OMS**: llamado <https://www.who.int/news-room/articles-detail/call-for-case-studies---strategic-action-for-urban-health>
- INTALinc-LAC Capítulo – Propuesta sometida abril 2024
- Número especial del Int. J Equit Health dedicado a equidad en accesibilidad territorial (oferta para ser editores invitados).

El doctorando ha liderado cuatro revisiones, verificadas en *Web of Science*, de artículos pertinentes al doctorado. Las revistas lo autorizaron a capacitar otros doctorandos como parte de la revisión:

- *Environment and Planning B: Urban Analytics and City Science* (SAGE). El 2 de mayo sometí la revisión de “Collaborative Development of an Open Science Urban Indicator Toolkit for Assessing Healthy and Sustainable Cities Internationally”. Capacité a las doctorandas *Elsury Johanna Perez* y *Jessica Otero Machuca*, mientras hacían pasantía de posgrado en OPS. [Q1]
- *Communications Medicine* (Nature). Dos revisiones. El 26 de septiembre de 2023 sometí la segunda revisión del artículo “Geospatial Investigations in Caldas, Colombia Reveal Variations in the Distribution of Mood and Psychotic Disorders”. La primera se envió el 23 de mayo de 2023, e incluyó capacitación a la Dra. *Ángela Suárez*, candidata a MPH en Johns Hopkins Bloomberg School of Public Health. [Q1]
- *Public Health Reports* (SAGE). Dos revisiones; el 30 de septiembre de 2022 y el 10 de marzo de 2023 del artículo Building a Roadmap to Health Equity: Strengthening Public Health Infrastructure in Indian Country. [Q1] Capacité a la Dra. *María Alejandra Gutiérrez* y la Ing. *Melisa Ramírez Salazar*.



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- [International Journal of Disaster Risk Reduction](#). Revisión del artículo “Enhancing Emergency Capacity: A Gradual Cooperative Accessibility Method Considering Time-Varying Traffic Congestion and Population Distributions”. [Q1] En curso.

El doctorado inició en febrero de 2020. Aunque el hacking de las cuentas de Gmail de la Universitat Autònoma de Barcelona retrazó las publicaciones al perder información valiosa sobre prototipos y entrevistas a actores clave, completamos la recolección de datos y las publicaciones planificadas.

Aporte metodológico para la salud pública

La metodología de investigación propuesta resuelve la dificultad que se presentaba para planificar servicios de salud de manera participativa, con datos válidos, y enfoque en la equidad. Esto permite alinear la agenda urbana y de salud, en línea con los Objetivos de Desarrollo Sustentable y las recomendaciones de Naciones Unidas y sus agencias especializadas UN-HABITAT y OMS. El enfoque complementa estudios tradicionales aportando evaluaciones prácticas que integran el nivel del tráfico, la equidad, y otros factores en plazos cortos, a bajo costo, en formatos comprensibles y adecuados para la política pública intersectorial, y la participación ciudadana.

Este set de clips describe el proyecto en

- < 1 minuto, clip <https://youtu.be/KeZUYEU9UHW>
- < 2 minutos, [resultados para radioterapia](#): <https://youtu.be/IG1QI1ruAGU>
- 6 minutos, visión del proyecto 2023 para OMS <https://youtu.be/TRFF6fkUt4>

Evidenciamos un creciente interés por parte de la sociedad civil, las autoridades y los usuarios de los datos, reflejado en el registro de cerca de 1500 personas en el [LinkedIn del proyecto](#).

Consolidación del equipo colaborativo

[Este enlace](#) ilustra el perfil de los integrantes del Proyecto Colaborativo AMORE que aportaron ideas y revisaron las publicaciones, aceptaron ser nombrados, y declararon sus conflictos de interés.

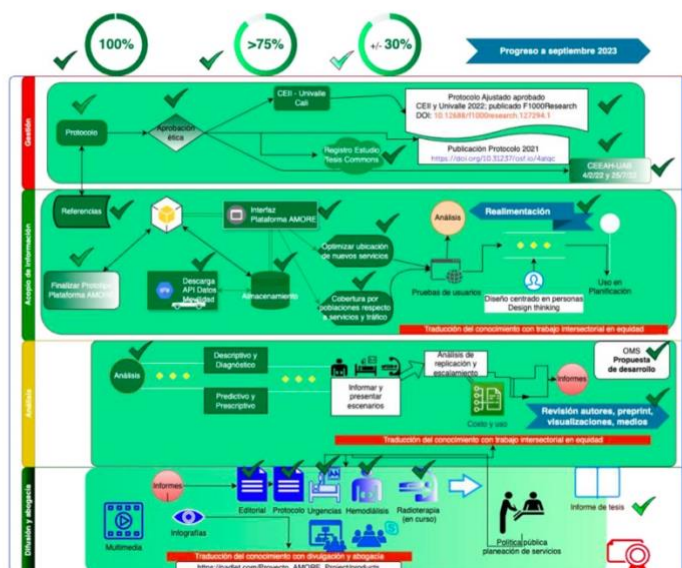
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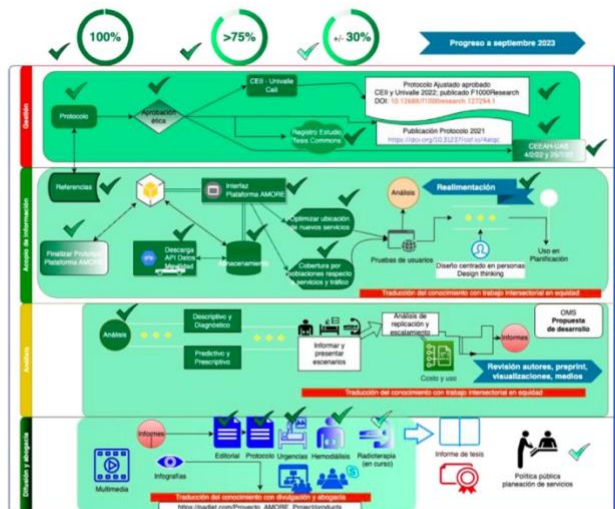


ANEXO A – Gráfico comparativo de progreso anual

1 - Informe de progreso 2024



2 - Informe de progreso 2023





Traffic Congestion, Health Services Accessibility, and Equity: A People-Centred, Data-Driven Approach to Urban and Health Planning.
Test Cases for Acute and Chronic Care Accessibility in Cali, Colombia.

Doctorando: Luis Gabriel CUERVO (Doctorando, Líder del Proyecto AMORE).
Supervisión: Ciro JARAMILLO MOLINA (director de tesis), Eliana MARTÍNEZ HERRERA (directora de tesis), Xavier BONFILL i COSP (tutor).
Portal y listado de colaboradores: https://padlet.com/Proyecto_AMORE_Project/products

Progresos desarrollo de tesis (11 de septiembre 2024 al 8 de septiembre de 2025)
Se cumplieron los requisitos para presentar el trabajo doctoral por compendio de publicaciones, paso necesario para el depósito de la tesis. Atendiendo las indicaciones del tutor, se revisó el documento de tesis y, el 2 de septiembre, se envió una nueva versión para aprobación junto con la respuesta detallada a las observaciones realizadas al documento original, remitido el 4 de julio de 2025.

Publicaciones doctorando Luis Gabriel Cuervo

DOI	ISO Revista	Año Cuartil JCR/Scimago	Factor de Impacto (5/1)	JCI	Percentil	Orden/Autores	Corresponsal
Publicaciones que constituyen el compendio para la tesis							
10.1186/s12939-024-02211-6	Int. J Equity Health	2024 Q1 / Q1	5,0 / 4,1	1,27	90*	1/21	Si
10.1016/j.lana.2024.100752	Lancet Regional Health-Americas	2024 Q1 / Q1	7,6 / 7,6	2,698	98**	1/15	Si
10.1136/bmjopen-2022-062178	BMJ Open	2022 Q1 / Q1	2,9 / 2,8	0,72	76	1/9	Si
Otras publicaciones							
10.26633/RPSP.2024.69	Rev. Panam. Salud Publica	2023 Q3 / Q2	2,0 / 2,0	0,5	46,8	2/6	No
10.12688/f1000research.127294.1	F1000Research	2022 NA / Q1				1/12	Si
10.1016/j.gaceta.2022.05.001	Gac Sanit	2022 Q3 / Q3	1,9 / 1,8	0,63	26,4	1/4	Si

*Editors Choice Aug 2024- Aug 2025.
**Editor's Pick for the issue.

En nuestras publicaciones abordamos un problema de política pública mediante la aplicación de métodos de investigación participativa, de implementación y de traducción integrada del conocimiento. Estas metodologías han permitido generar evidencia para orientar políticas públicas basadas en datos y en enfoques intersectoriales, considerando la geografía y la salud como determinantes sociales. Aunque el objetivo central de la tesis es aportar mediciones y predicciones, también se integraron componentes de apropiación social y traducción del conocimiento, con un enfoque explícito en la equidad y la justicia social, buscando un impacto tangible. Esta orientación quedó plasmada en el protocolo, la editorial y las publicaciones que conforman el compendio de la tesis.¹⁻⁵

Desde el inicio del doctorado han surgido algunas propuestas de evaluación dinámica de la accesibilidad, es decir, que consideran la congestión del tráfico. Nuestro enfoque mantiene su carácter distintivo al haber sido diseñado, aplicado y validado con aportes de usuarios del conocimiento y de actores que participan en la planificación urbana y de servicios de salud.

El proyecto se desarrolló con un enfoque centrado en las poblaciones, aplicando pensamiento de diseño y una perspectiva de equidad. La integración de datos abiertos y macrodatos permitió generar insumos útiles para informar políticas públicas y debates entre actores interesados, la mayoría de ellos personas educadas, pero no especializadas en las múltiples disciplinas relevantes como geografía, ingeniería, demografía o investigación en servicios y sistemas de salud.

Un resultado afortunado de esta aproximación, alcanzado de manera inusualmente rápida, fue la consideración del estudio dentro del Plan de Desarrollo 2024–2027 de la ciudad de Cali y en el acervo científico que informa el Plan de Ordenamiento Territorial actualmente en desarrollo.⁶⁻⁸



Metodología, replicabilidad y difusión inicial

La metodología y los informes buscan que la propuesta sea eficiente, útil para el monitoreo y la planificación urbana, y además replicable, adaptable y escalable.

El Observatorio Urbano Cali Cómo Vamos, la prensa nacional colombiana (El Tiempo) y medios locales divulgaron notas y entrevistas destacando los resultados publicados y la devolución de hallazgos a los actores locales. Esta retroalimentación se realizó en un evento internacional organizado por la Universidad del Valle, en Cali, en septiembre de 2024.⁹⁻¹⁶

Asimismo, se aplicaron buenas prácticas en el desarrollo y transferencia del conocimiento, incorporando principios de investigación en implementación e innovación social. Se recibieron aportes de las partes interesadas para el diseño de la plataforma digital interactiva, que no solo presenta los datos de los informes, sino que también permite a los usuarios del conocimiento probar diferentes escenarios modificando variables, de manera que resulten útiles para la toma de decisiones.

Otra buena práctica fue involucrar al equipo de científicos de datos en todas las etapas del proceso, junto con los usuarios del conocimiento: desde la conceptualización y el desarrollo, hasta la implementación y la elaboración de informes.¹⁷⁻²¹

Aspectos novedosos y adopción del enfoque en otros estudios

Algunos elementos innovadores y prácticos de nuestro enfoque han sido emulados o destacados en investigaciones externas. Un ejemplo es la publicación de las interfaces de nuestra plataforma interactiva en la web, lo que permite que los datos hablen por sí mismos y que los lectores puedan explorar escenarios y enriquecer las discusiones con sus propios insumos. Este modelo fue adoptado por un proyecto en Nigeria, aunque sin el componente de identificar ubicaciones idóneas para nuevos servicios.²²

El grupo colaborativo del proyecto doctoral Análisis con Macrodatos para Orientar Resultados en Equidad (AMORE) está conformado por alrededor de medio centenar de voluntarios, de los cuales la mitad han sido coautores de publicaciones.²³ Varios miembros han presentado el proyecto en eventos convocados por distintos sectores, incluyendo en el último año.^{9,10,24} Todos han aportado al desarrollo del estudio, y algunos han recopilado testimonios o materiales que amplían el contexto, disponibles en el [Padlet™](#) del proyecto.²⁵

Desarrollos de la línea de investigación vinculados al proyecto

Algunos investigadores han ampliado la línea de trabajo del proyecto doctoral.

- Una tesis de maestría en la **Bloomberg School of Public Health de la Universidad Johns Hopkins** evaluó la plataforma digital interactiva del Proyecto AMORE desde la perspectiva de quienes participan en la planificación urbana y de servicios.^{26,27}
- En la **Universidad del Valle (Colombia)**, una profesora culminó su maestría en salud pública con un estudio que comparó los resultados descriptivos y gráficos del Proyecto AMORE con indicadores tradicionales de desigualdad, basados en áreas bajo la curva.²⁸
- El profesor **Jorge Gallego Méndez**, ingeniero topográfico y especialista en geomática, está utilizando los datos del proyecto para explorar nuevas aplicaciones en ordenamiento territorial y planificación de servicios.^{29,30}

En junio de 2024 se vinculó al proyecto la maestranda en comunicación científica Lic. **Laura V. Molina Benavides**, comunicadora de la Secretaría Distrital de Salud de Bogotá y estudiante de la **Universidad Internacional de Valencia**. Su participación permitió consolidar un plan de comunicación y apropiación social del conocimiento, al que contribuyeron varios integrantes del equipo colaborador y los directores de tesis.



Como parte de esta estrategia, se publicaron materiales en [Figshare](#), [Thesis Commons](#), y YouTube. Estos pueden accederse a través del Padlet.²⁵

Difusión, apropiación y aplicación de nuestra investigación en la gestión urbana

Durante este año se consolidaron alianzas estratégicas para implementar los resultados y favorecer la adopción de la metodología en salud pública. Entre ellas destacan la fundación internacional [City Cancer Challenge – C/Can](#) que trabaja en Cali con la fundación [ProPacífico](#), así como la red Ciudades Cómo Vamos, que incluye el observatorio ciudadano [Cali Cómo Vamos](#), promotor activo de la divulgación y aplicación de los hallazgos.

En el último año se realizaron dos talleres con ProPacífico y City Cancer Challenge para debatir con actores locales cómo reducir los tiempos de diagnóstico y mejorar la adherencia al tratamiento del cáncer de mama en Cali.³¹ Estas instituciones apoyan la gestión municipal y promueven la rendición de cuentas de la administración pública. Sus directoras ejecutivas, junto con sus equipos técnicos y de comunicación, colaboraron en la difusión y promoción de las recomendaciones del estudio.

Otros espacios de divulgación y promoción del enfoque se desarrollaron con organizaciones intergubernamentales. El coordinador de emergencias de la OPS/OMS invitó al director de tesis a presentar la metodología en un panel regional de coordinadores de preparación y respuesta a emergencias, celebrado en octubre de 2024 en Quito.²⁴ Asimismo, la OPS y el **Banco Interamericano de Desarrollo** firmaron un acuerdo para explorar métricas de accesibilidad que incorporen la congestión del tráfico. Este trabajo busca ofrecer a los países de la región fuentes de datos abiertos y macrodatos para desarrollar mediciones y monitoreo en zonas metropolitanas, complementando los estudios realizados en áreas sin congestión.³²

Finalmente, otra colaboradora presentó el proyecto como ejemplo del uso de **inteligencia artificial en la planificación de la salud pública** en un curso de educación continuada.³³

Difusión de las publicaciones

Finalmente, otra colaboradora presentó el proyecto como ejemplo del uso de inteligencia artificial en la planificación de la salud pública en un curso de educación continuada.

Descargas a 7 de septiembre de 2025.

Tema	DOI	Revista	Publicado	Preprint +Publicación
Radioterapia	10.1186/s12939-024-02211-6	Int. J Equity Health.	15-08-2024	991+ 4597 5,588
Evaluación decisores	10.26633/RPSP.2024.69	Rev. Panam. Salud Publica.	14-08-2024	NA + 1339 1,339
Hemodiálisis	10.1016/j.lana.2024.100752	Lancet Regional Health-Americas.	03-05-2024	877 + NA NA
Emergencias de alta complejidad	10.1136/bmjopen-2022-062178	BMJ Open.	01-09-2022	1155+ 7,321 8,476
Protocolo	10.12688/f1000research.127294.1	F1000Research.	28-11-2022	NA+ 1,178 1,178
Editorial	10.1016/j.gaceta.2022.05.001	Gac Sanit.	11-06-2022	NA+ 5501 7,731

Las publicaciones ya han sido citadas en literatura científica indizada, así como en diferentes sectores, disciplinas y contextos geográficos.²⁵



Traffic Congestion, Health Services Accessibility, and Equity: A People-Centred, Data-Driven Approach to Urban and Health Planning. Test Cases for Acute and Chronic Care Accessibility in Cali, Colombia.

Oportunidades emergentes para publicación relevante

Fuimos seleccionados en un proceso competitivo para contribuir con el capítulo “3. Using open and big data with diverse interest holders to improve urban accessibility in congested cities” en el libro *Urban Planning and Accessibility in Latin America: Spatial, Mobile and Socio-cultural Dimensions*, que será publicado por Routledge Accessibilities. El capítulo se encuentra actualmente en revisión por pares.

Asimismo, la Organización Mundial de la Salud (OMS) seleccionó el proyecto para la elaboración de un estudio de caso aplicando el [enfoque estratégico de Salud Urbana de la OMS](#). El proceso está pausado mientras la organización redefine prioridades debido a restricciones financieras, como se indica en el llamado oficial: <https://www.who.int/news-room/articles-detail/call-for-case-studies---strategic-action-for-urban-health>

Durante el último año, el doctorando también completó dos revisiones por pares verificadas en [Web of Science](#), de artículos directamente pertinentes al doctorado:

- *BMJ Innovations. Technology and Innovation in Advancing Health Equity* (19 de febrero de 2025).
- *International Journal of Disaster Risk Reduction. Enhancing emergency capacity: A gradual cooperative accessibility method considering time-varying traffic congestion and population distribution*. Sep 21, 2024.

Aporte metodológico para la salud pública

La metodología de investigación desarrollada responde a un reto central de la política pública: la dificultad de contar con datos útiles para planificar el urbanismo y los servicios de salud de forma participativa, con información válida, accesible y enfocada en la equidad.

Este enfoque contribuye a alinear las agendas urbana y sanitaria con los Objetivos de Desarrollo Sostenible (ODS) y con las recomendaciones de Naciones Unidas. Complementa los estudios tradicionales al ofrecer evaluaciones prácticas que integran factores como el tráfico, la equidad y otras variables, en plazos cortos, con bajo costo y en formatos comprensibles para la política pública intersectorial y la participación ciudadana.

Para quienes deseen familiarizarse rápidamente con el proyecto, se recomiendan estos videos:

- < 1 minuto, clip <https://youtu.be/KeZUYEU9UHw>
- < 2 minutos, resultados para radioterapia: <https://youtu.be/IG1Ql1ruAGU>
- 6 minutos, visión del proyecto 2023 para OMS <https://youtu.be/TRFF6flkUt4>

El interés de la sociedad civil, autoridades y usuarios de los datos se refleja en los más de dos mil seguidores en [LinkedIn del proyecto](#), lo que representa un crecimiento del 30 % respecto al año anterior.

Consolidación del equipo colaborativo

El [perfil de los integrantes del Proyecto Colaborativo AMORE](#) reúne a quienes aportaron ideas, revisaron publicaciones, aceptaron ser nombrados y declararon sus conflictos de interés.²³

La [línea de tiempo del proyecto](#) ilustra sus principales desarrollos.³⁴

Las presentaciones realizadas por diferentes colaboradores en diversos escenarios geográficos y temáticos evidencian la apropiación del conocimiento y un liderazgo basado en la coordinación de



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esfuerzos y la descentralización de las respuestas. Este modelo ha favorecido la divulgación del proyecto y su impacto en políticas y prácticas.

La tesis contribuye a la misión del programa doctoral de avanzar la salud poblacional mediante herramientas y metodologías de la epidemiología y la traducción del conocimiento. Su propósito es mejorar los resultados en salud y responder a las necesidades de personas y comunidades, abordando temas clave como salud urbana y pública, justicia social, equidad en salud, sistemas de salud, investigación en implementación y calidad de la atención.

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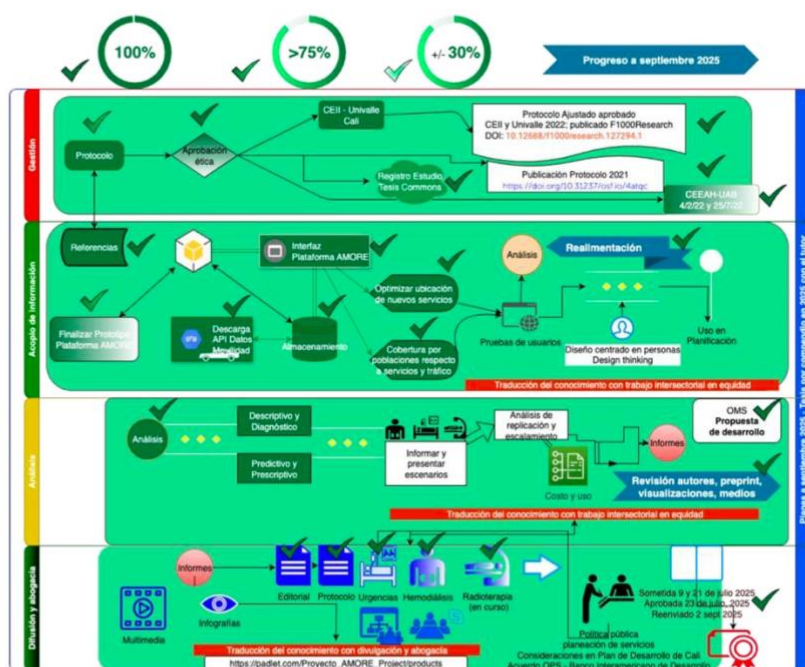
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ANEXO A – Gráfico comparativo de progreso anual - Informe de progreso 2025





"I asked, 'How far is the airport?' He said, '25 minutes.'"

—Ismo Leikola, Finnish comedian.⁴⁶⁴

