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 employed a methodology to evaluate and forecast the cumulative opportunities for residents to access radiotherapy services in Cali, Colombia, while accounting for traffic congestion from an equity perspective. Furthermore, we identified 1-2 optimal locations where new services would maximise accessibility. We utilised open data and publicly available big data.

Methodology:

Using a people-centred approach, we tested a web-based digital platform developed through design thinking. 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 search heuristics to identify optimal locations for new services. We predicted accessibility cumulative opportunities (ACO) for traffic ranging from peak congestion to free-flow conditions at 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-minute Accessible Catchment Area (ACO) isochrones for car journeys. These isochrones connect the population-weighed 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 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 maximise the 20-minute ACO during peak-traffic congestion.

Results:

Traffic congestion significantly diminished accessibility to radiotherapy services, particularly affecting vulnerable populations. For instance, urban 20-minute ACO by car dropped from 91% during free-flow traffic to 31% during peak traffic for the week of 6–12 July 2020. Specific ethnic groups, individuals with lower educational attainment, and residents in 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.

Study in context

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 to vulnerable populations. Moreover, people increasingly prefer to visit healthcare sites where they spend their daily lives rather than travel great distances or sit in traffic. Direct and indirect costs associated with long journeys impact adherence, clinical outcomes, and patients' and their families' 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 tool for both public and private sectors to strategically plan the establishment of new healthcare sites, focusing on urban accessibility to critical services such as radiotherapy. Utilising relatable cartography and descriptive statistics, the tool effectively communicates 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 integrate health equity with urban and health services planning.

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

This study supports a fundamental shift in approaching accessibility measurements for health services 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 stand to benefit from incorporating these measurements into their health and urban planning policies. This integration can lead to improvements in overall accessibility, efficiency, and public participation. Moreover, the study holds the potential to influence policies that prioritise 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 and authorisations.

Introduction

Traffic congestion reduces accessibility to health services and might affect population groups differently. However, measuring congestion has been elusive for practical reasons.[1] 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.[1–4] 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.[5] The DGAM showed that under usual traffic congestion conditions, urban accessibility to tertiary care emergency services dropped from 84% to 38%, revealing a previously overlooked problem.[6–10] Reduced accessibility can adversely impact the overall quality of healthcare, life, and health outcomes.

However, studies on accessibility to service provision are often done with minimal stakeholder involvement, disregarding knowledge translation recommendations.[11–18] Furthermore, these studies employ complex methods and communicate findings to a specialised audience, which may not always be directly related to healthcare. Such assessments are usually cumbersome to update and rarely offer interactive options, rendering them ineffective for testing different scenarios, assumptions, monitoring, and planning.[1,8,19–23]

A research project in Cali's informal settlements of the western peripheral Commune 18 produced qualitative data highlighting the problems people face when accessing outpatient services they frequently use, such as cancer treatments or haemodialysis.[24–26] These patients and their families can face financial hardship from the direct and indirect high costs (e.g., lost wages and transportation) of lengthy travel to receive such services.[27–34]

Radiotherapy is an essential component of cancer care.[35] 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.[36–38].[39] 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. Measuring the effects of traffic congestion on accessibility among populations enables data-driven approaches to address underlying issues, such as 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 systematically cover transportation.[40] 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.[41]

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.[27,42–45] Poor geographical accessibility to cancer treatments diminishes the quality of care and is associated with poor clinical outcomes.[38,41,46–50]

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 and cater to the healthcare needs of Cali's diverse population.

Methods:

This study outlines a ground-breaking, people-centred approach to generating DGAMs for health services. The investigators comprise a multistakeholder international team seeking to promote data-driven health services planning and health equity.[51,52] 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.[53]

We developed the AMORE web-based platform to integrate open sources (adjusted census microdata matched to TAZs), add travel times and perform all measurements. We used design thinking throughout the platform's development. 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.[16,53] We identified radiotherapy services in Cali using the Colombian National Health Services Registry. We obtained travel times big data from Google Distance Matrix API for the weeks of July 6–12 and 23–29 November 2020.[53]

The AMORE web-based platform displays accessibility cumulative opportunities (ACO), 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).[54] 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 sociodemographic population characteristics.

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. This location makes Cali the only major Colombian city with access to the Pacific coast. 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.

Radiotherapy Services

In 2020, Cali registered five radiotherapy facilities in the Colombian Special Registry of Health Services Providers (REPS in Spanish). Radiotherapy services are close to the north-south corridor on the lower part of the western Andean slopes and the western valley, where most residents in high-income housing live. 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. Four are in the western part of Cali and one in the south, all in well-off areas (Figure 3). These radiotherapy facilities have extended hours from Monday to Saturday, providing crucial healthcare services.

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.[7,53,55,56] 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)[57,58]; administrative divisions of Cali obtained from the Colombian IDESC Geoportal, Traffic Analysis Zones (TAZ), and census block sectors[59,60]; Google's Distance Matrix API; and information about the five radiation therapy services in Cali. The complete list of variables can be found in the study in the protocol.[53]

For this baseline assessment of urban Cali, 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. Travel times varied substantially during the COVID-19 pandemic, and it is unclear how this influenced Google Distance Matrix algorithms.[61] Empirical and anecdotal reports suggest they remained accurate. Radiotherapy facility data was obtained using REPS service codes 711 (radiotherapy as complementary or diagnostic treatment) and 408 (outpatient radiotherapy). These centres were registered under both service codes in 2020 and remained unchanged as of 30 November 2023.[62] We did not include providers offering only nuclear medicine (code 715).

Statistical analysis

This analysis focuses on frequencies and bivariate analyses to represent cumulative opportunities as a measure of accessibility.[54] Critical variables for this report are travel time from residential TAZs to the TAZ hosting the radiotherapy service with the shortest journey time and the housing and sociodemographic characteristics of the population, as recorded in Colombian national census microdata. The AMORE web-based platform displays absolute and relative population per travel time threshold measured for each of the nine traffic congestion levels, ranging from free-flow to peak traffic congestion. 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.

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 living in 596,051 households in 582,814 housing units. 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. [63]

The resulting population is 2,258,823 urban residents living in 507 TAZs and comprising 596,051 households within 582,814 housing units. Figure 1 summarises the sociodemographic characteristics of the population.[53] Cali consisted of 22 communes in 2020, but began transitioning to becoming a Special District with six localities in 2023. [64–67] 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.

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. Most of the 935,699 middle-income Cali residents (about 41% of the population) live in 257,153 households in the central and southeast corridors of the city (Figure 2 and Figure 3).

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). 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.[53]

Effects of traffic on accessibility to radiotherapy services: Baseline results

Figure 1 shows the situational analysis interface for July 2020 with absolute population data. Tables 1 and 2 present the absolute and relative effects of peak traffic on the 20-minute ACO for the Cali population. Data are disaggregated by household income level, ethnicity, gender, age, education level, and civil status as measured in July 2020 and November 2020.

Figures 4 and 5 show the interface for July and November, respectively, with a travel-time threshold of 20 minutes and relative population figures. The 20-minute threshold was arbitrary and found reasonable in most focus groups. There is no set national or international standard for these travel time thresholds. Figure 6 complements these data, showing the variations between the July and November assessments, with the resulting 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 during periods of traffic congestion, most people living in low-income housing had lower geographic accessibility to radiotherapy services, both in November 2020 and July 2020. Our analysis showed that travel times represent an access barrier for low-income households, areas with high population density, and individuals residing in peripheral sectors of Cali (Figure 6).

Traffic congestion exacerbated inequities by disproportionately impacting the poorest populations on the outskirts of Cali (Table 1, Figure 6, and Figure 7). 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 accessibility rates of 82.6% in July compared to 89.5% in November (Table 1 and Figure 6), as many of the services are in high-income sectors of Cali.

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. The small Palenque population, concentrated in a few neighbourhoods near the 20-minute ACO thresholds, benefited the most 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 (31.3%). However, as traffic congestion eased, accessibility rates became more uniform across different marital statuses, ranging from 60.5% for couples to 66.5% for widowers.

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

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. Optimising urban accessibility during peak traffic hours consistently pointed to the need to add new services in the eastern sector of *La Base* with enough capacity to absorb the demand. 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).

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 Figure 8).

Adding services in two new locations would significantly increase Cali's accessibility to radiotherapy services. While July and November predictions point to four different geographical areas, the recommended sectors are in the northeast and southeast and are adjacent (Figure 8). 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 (Figure 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.

The evidence, drawn from measurements in both July and November, clearly shows the positive impact introducing new radiotherapy services would have on accessibility, particularly in eastern Cali. Moreover, the data also shows 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 represents a substantial number of people.

Other analyses

Comparing July and November 2020

We predicted the impact on cumulative accessibility for July and November 2020 by adding services in 1–2 locations to optimise urban accessibility. We present the relative figures in Table 2 and Figure 9 and the absolute figures in Table 3. Both tables estimate the impact of adding services in one and two sectors. We found that new services have the potential to dramatically reduce inequities in accessibility to health services, leaving radiotherapy services within a 20-minute journey by car for most inhabitants.

Figure 11 and Figure 12 illustrate the AMORE web-based platform interface with the graphs and data from the predictions for adding services in one and two sectors, respectively. The charts depict the notable reduction of inequities in relative figures (Table 1), complementing the absolute figures from Table 2.

Discussion

Access to radiotherapy services in Cali presents significant challenges for most of the population, particularly residents in outlying areas. The city's layout and demography have changed, and land use and health services planning can be updated, benefitting from this approach and travel time data for data-driven integration of health and equity with the urban agenda. [68,69] Our new data indicates populations in the city's east and outlying areas are being left out. This should challenge traditional approaches and support action to correct social injustice and inequities.[48]

Our findings highlight the potential for dramatic improvements achievable by relevant decision-makers by promptly adding 1–2 new radiotherapy services to eastern Cali, strategically located to optimise accessibility. Traditionally, radiotherapy services have been collocated with tertiary care emergency services, but none exist in Cali's east.[7,38] Recently, stand-alone centres have been developed elsewhere, prompting consideration of whether Cali should have a tertiary care hospital 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. These services must have the capacity to meet the high demand from the covered populations 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.

We found traffic congestion disproportionately affects residents in outlying areas, low-income housing, Afro-descendants, and residents with lower educational attainment and younger age. This study brings attention to the consolidation of the "inverse care law" to radiotherapy services in Cali, mirroring patterns seen in tertiary care emergency services and haemodialysis.[7,70] The higher impact on vulnerable populations exacerbates social injustice and health inequity.[71,72] As previous studies have suggested, residents in informal settings, like others facing vulnerability and inequity in accessibility, are more likely to be disconnected from formal transportation modes. Exploring this further could provide valuable insights, especially if the study were replicated for other means of public transportation.

This study underscores the imperative of allowing patients to utilise reachable services with the shortest journeys. Since radiotherapy is an integral part of a comprehensive treatment, service providers should avoid fragmenting healthcare services to maximise accessibility and quality of care.[36,37,73] Recognising that many individuals may face challenges accessing the service providers with the shortest journeys, our study findings are intended to encourage and inform societal agreements to improve accessibility to such radiotherapy services. This challenge will likely extend to other cities in Colombia and beyond, amplifying inequities. The study's approach has the potential to assess and monitor such issues in various contexts.[27,29,74–76]

This study's approach opens avenues for implementing accessibility monitoring and evaluation, suggesting periodic (e.g., annual, semestral) assessments and exploring the economics of different approaches to enhance accessibility. For instance, by informing land use and health services planning about adding services to existing public infrastructure, as tested in early AMORE web Platform prototypes.[77] The release of projected census data in 2024 allows updating these findings and integrating this approach into urban observatory networks.[78,79] This also presents a chance to promote community data initiatives involving intersectoral and multistakeholder collaboration. For instance, addressing the scarcity of data for informal settlements, popular neighbourhoods, or Cali's new districts to tackle health equity and social justice issues for populations that often lack a voice or remain neglected.[26] Another aspect involves applying the approach to promote accessibility to specialised radiotherapy services, such as brachytherapy.

Our findings emphasise the need to monitor demand, building on open and big data integration opportunities.[19] 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 for radiotherapy needs would benefit such deliberations.

Gaining knowledge on transport means used by patients and acting on factors influencing accessibility beyond travel times.[41,80] For example, distributing subsidies that address social justice or organizing mobility services to promote health services accessibility, especially for outlying urban areas.

Given the substantial demand adding these services in the appropriate locations would address, these findings underscore not only the urgent need for additional radiotherapy services that all residents can access but also highlight the importance of data-driven analysis for the location of new services. Unfortunately, there are no tertiary care level or large public hospitals adjacent to the sectors that optimise accessibility to radiotherapy. However, these insights provide valuable parameters for health services planning and strongly advocate re-evaluating land-use policies in Cali.

Key results

The impact on health equity, as our findings show, is substantial and multifaceted. Our findings predict that adding strategically located radiotherapy services would dramatically enhance accessibility opportunities throughout the city, bringing them to levels currently found in low-traffic congestion situations. Our assessments highlight the challenges, and our predictions present viable solutions plus crucial data that stakeholders across different levels of governance can use for advocacy, planning, and monitoring. These stakeholders include government authorities, civil society and opinion leaders, academics, advocates, and radiotherapy service providers and users. Of particular significance are those who actively engaged in this participatory research project.[1,13,81,82] We invite policymakers to consider adopting strategies like the one we reported to develop fairer transportation subsidies by grading them according to accessibility.

Our evaluations proved that a multistakeholder group supported by data scientists could generate repeated geographical accessibility assessments for three services for an entire city in an LMIC.[19] It was also possible to deliver these findings in a format relatable to participating stakeholders, making it feasible to communicate these findings to non-specialised audiences at diverse events and urban observatories.[56,83]

This study provides a valuable analysis of accessibility opportunities within the Colombian health system. It also sheds light on an accessible and rapid approach to estimating the impact of traffic congestion that could prove helpful to stakeholders and sectors (e.g., health, urban planning, smart city, economy) in planning for better health and equity and practical monitoring of geographical accessibility.[18,69]

Interpretation

These findings empower stakeholders to engage in informed, 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.[84]

Care models for bustling cities should incorporate health service quality determinants, such as travel times. It is crucial to recognise that radiotherapy, typically involving comprehensive care, is inherently linked to delivering other services, including psychological support, rehabilitation therapies, nutritional guidance, pain management, and palliative care. Patients, therefore, require frequent access to these services, and health services planning requires considering the integration of services, including chemotherapy that might be given in combination with chemotherapy.[37–39,73,85] Future research could 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.[73]

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 reasonable travel times from where most of the population resides.[39,85,86]

In this context, balancing the advantages and disadvantages of centralising versus decentralising radiotherapy services is essential. The geographical segregation of populations in Cali and the concentration of 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.[87]

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 (Figures 2 and 3). Restrictions that prevent patients from accessing services available in every sector could further reduce accessibility. For instance, the Fundación Valle de Lilí radiotherapy service, in the southernmost part of Cali, is the sole provider for the densely populated southern areas of the city. Suppose a health maintenance organisation/insurer (EPS/EAPB, in Spanish) does not have a contract with this provider or assigns local patients in southern Cali to a different provider. In that case, neighbours will not benefit from its proximity. The low-accessibility and inequity gradients highlight the urgency of implementing reforms to address the fragmentation of health service delivery.

Testimonies from participatory community research teams and patients illustrate the plight of patients facing lengthy journeys for cancer and other high-cost treatments, such as haemodialysis.[24,25,70] Our findings suggest that swift, notable improvements are achievable through policies and actions that incentivise service providers and payers to broaden accessibility.

Strategically adding radiotherapy services will benefit the overall population across all economic strata and ethnic groups, with advantages for currently underserved groups (see Table 1, Table 2, Figure 9, and Figure 10). The evidence shows how adding two service sites increased the number of inhabitants within the 20-minute ACO in both assessments and across all economic strata and ethnic groups, notably impacting those currently underserved. Studies should be promoted to 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; thus, the fragmentation of health services might have yet to introduce bias in the published tertiary care emergency services assessment. However, such a law is not in place for chronic ambulatory services like radiotherapy; therefore, patients might only be able to access some radiotherapy-providing IPSs.[7,88] 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.[12,89]

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.[1,7,70]

Generalizability

The availability of travel-time big data allows for assessing various transportation modes. This approach applies to a broad spectrum of diagnoses and treatments, provided there is accessible georeferenced information. 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. The resulting assessments could inform land-use and health services planning and contribute to aligning radiotherapy and other cancer treatments with universal health coverage.[90]

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 approaches 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.

Notably, international policies and mandates are accelerating digitisation and datafication trends in many countries. This study's approach is transferable and can be replicated in other settings with traffic congestion, provided the essential data is available. Using population-weighed TAZ centroids instead of blocks reduces the overall costs associated with travel-time data while allowing for precise estimates.

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.[53]

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.

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.[88] 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, it provides a broad, optimistic assessment of accessibility. However, it reflects those populations that, even in the best-case scenario, would be beyond the assessed travel-time threshold. 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 and all radiotherapy services activated.[89]

We did not include cost-effectiveness analyses or accurate demand and capacity estimates for new services.

Radiotherapy services are provided to the broader metropolitan area and neighbouring cities; this study focused on urban Cali.

Conclusions

This study advocates for using DGAMs to monitor accessibility in cities where traffic congestion might be amplifying inequities. 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 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.[17,18] The impact of such engagement differs from this report's focus.[56] The AMORE Project interactive interface is publicly available.[12,15,53,81,91,92]

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.

Funding

This study received no external funding.

Ethical considerations

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.[93,94]

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.[53]

Travel-time data used by the AMORE web-based platform is available from OpenScience [July DOI 10.17605/OSF.IO/XDA87 and November DOI 10.17605/OSF.IO/FMJ2X], and 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.

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Disclaimer

The depiction of boundaries on included maps does not imply the expression of any opinion of publishers concerning the legal status of any country, territory, jurisdiction, area, or its authorities. Maps are provided without any warranty, either express or implied. Figures 3 and 8 were obtained using Google Maps©. Other maps in this report were obtained from Mapbox© through PowerBi.

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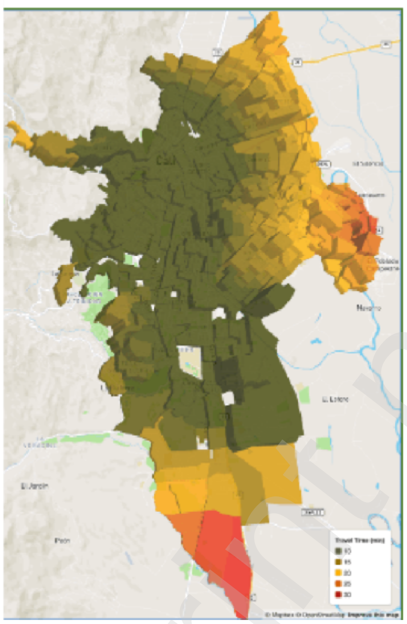
20-min accessibility rates to radiotherapy drop as traffic congestion grows.



Supplemental material

Recording: https://youtu.be/lQsGmbGWyZI

Tables

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%	*22.3%*	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

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
	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*
Rrom (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*

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

Figures

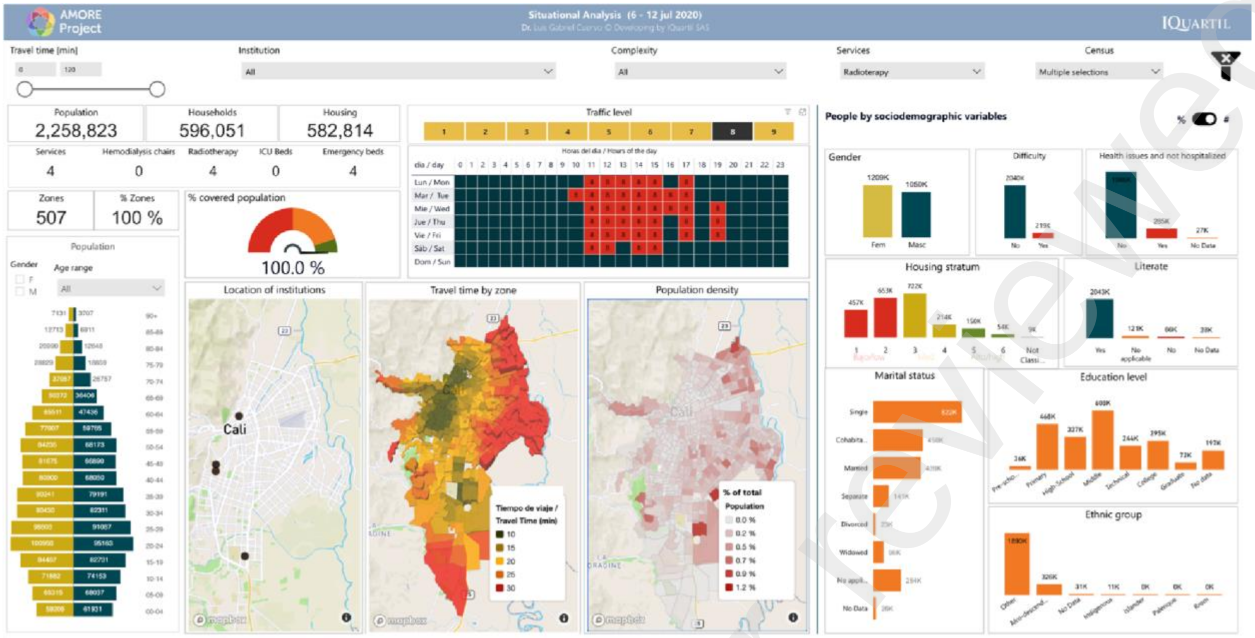


Figure 1: AMORE web-based Platform demographics interface (absolute figures)

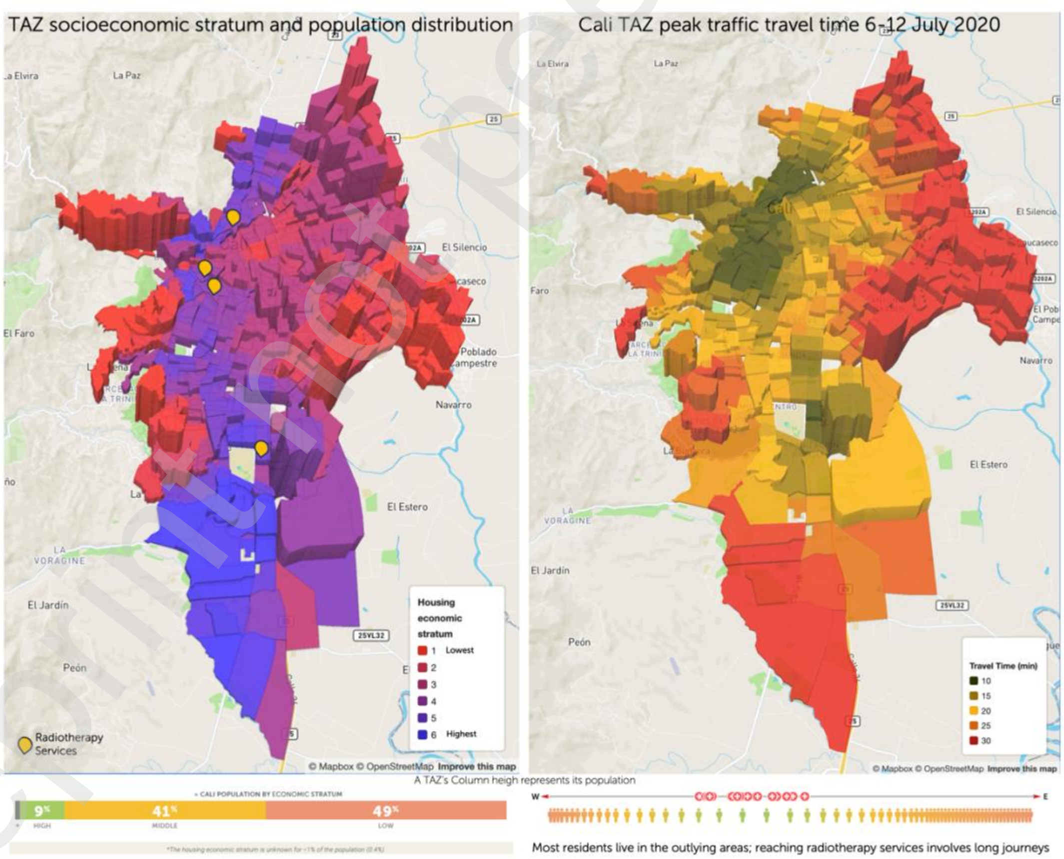


Figure 2. Cali's 2020 population distribution by housing economic stratification and travel time

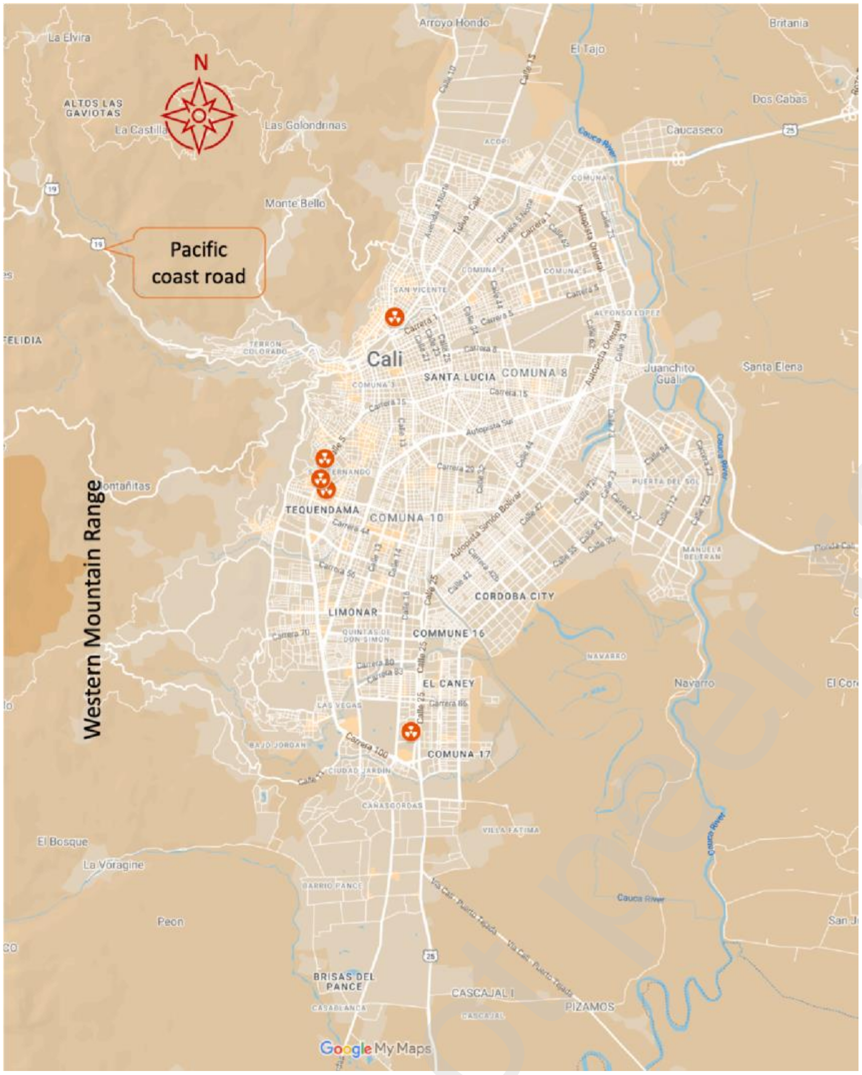


Figure 3: Location of radiotherapy services in 2020.

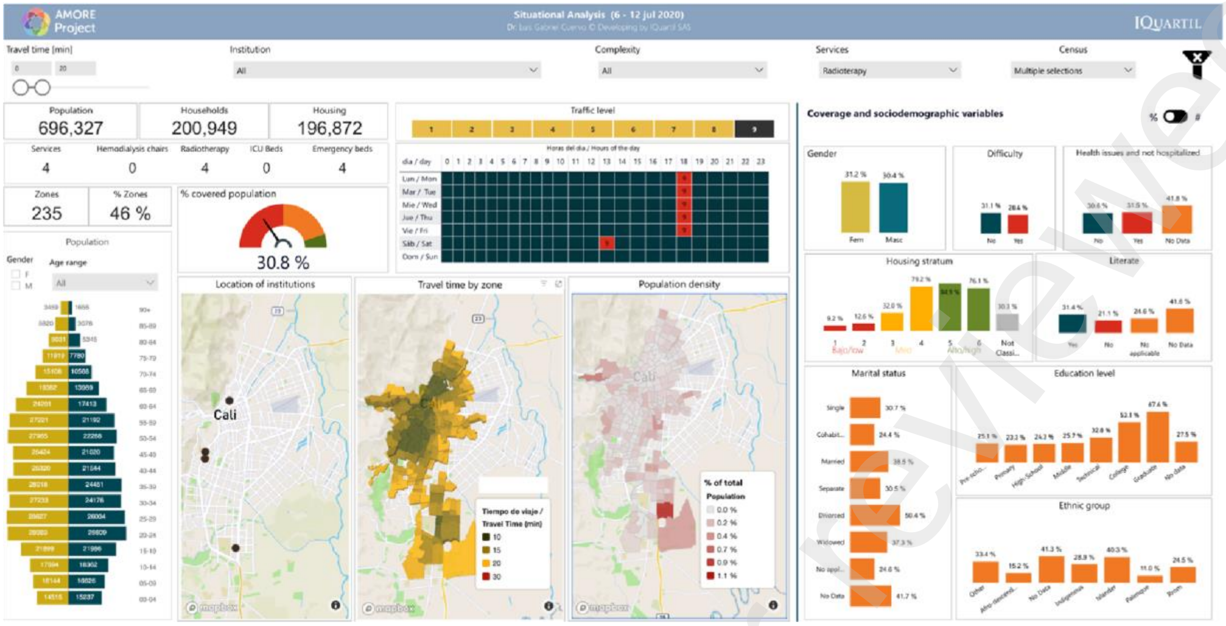


Figure 4 20-minute ACO by car to radiotherapy 6–12 July 2020 (relative)

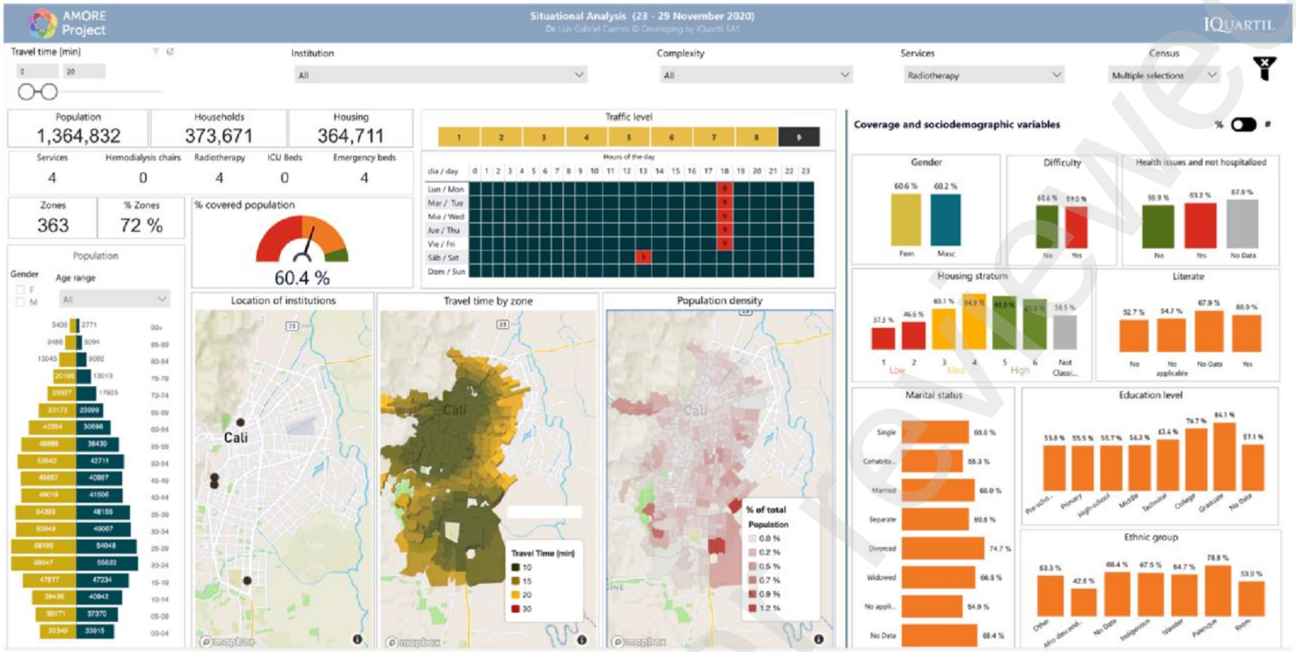


Figure 5 20-minute ACO by car to radiotherapy 23–29 November 2020 (relative)

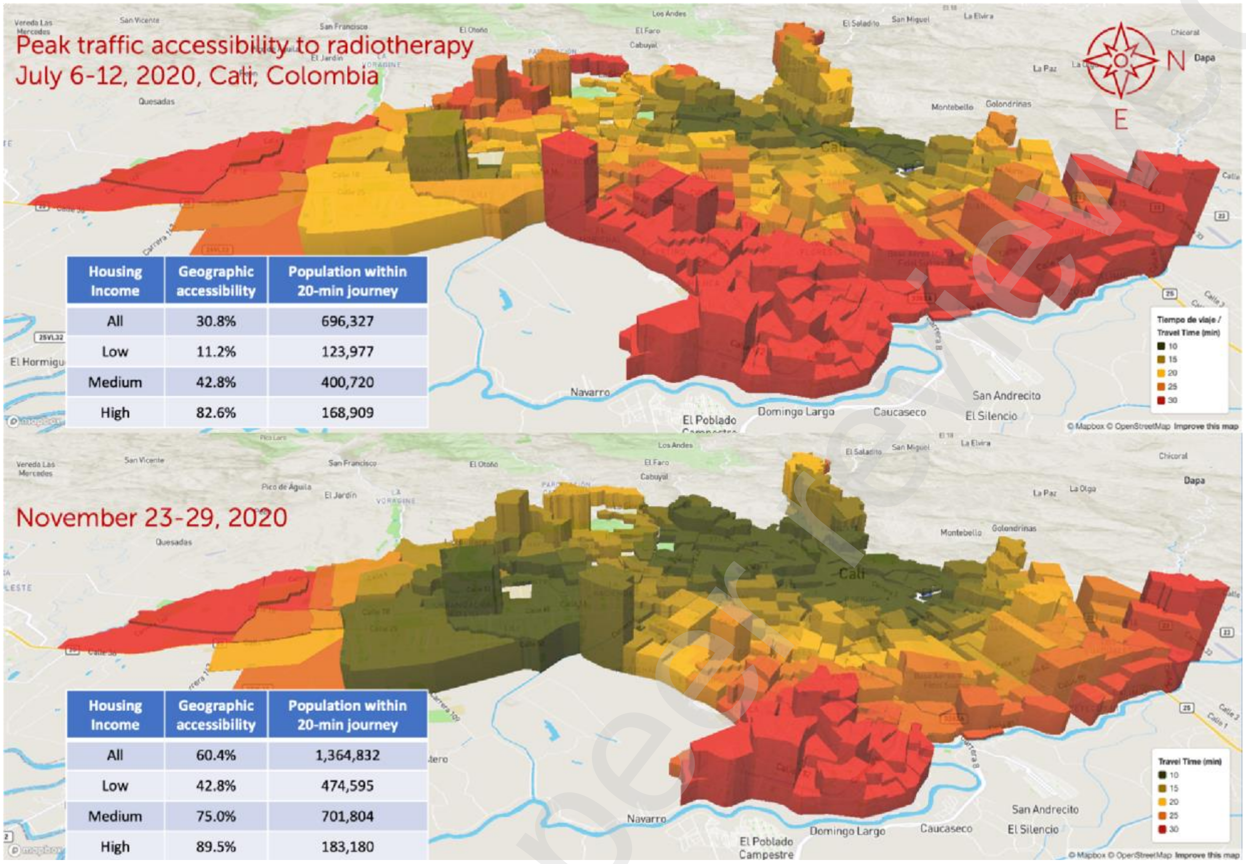


Figure 6. Assessed accessibility in July and November 2020 by economic stratum and location. Column height represents the TAZ population.

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

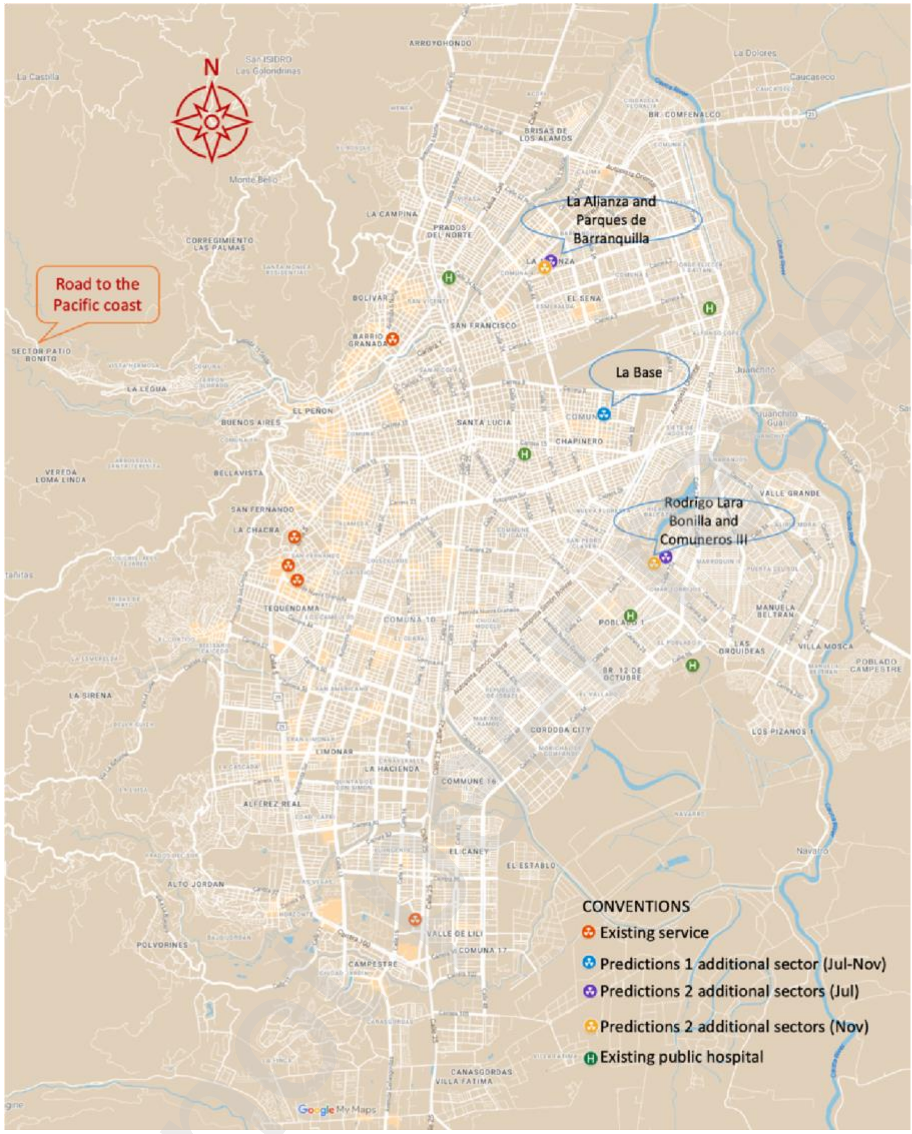


Figure 8. Locations to optimise urban accessibility, adding services in one vs. two sectors.

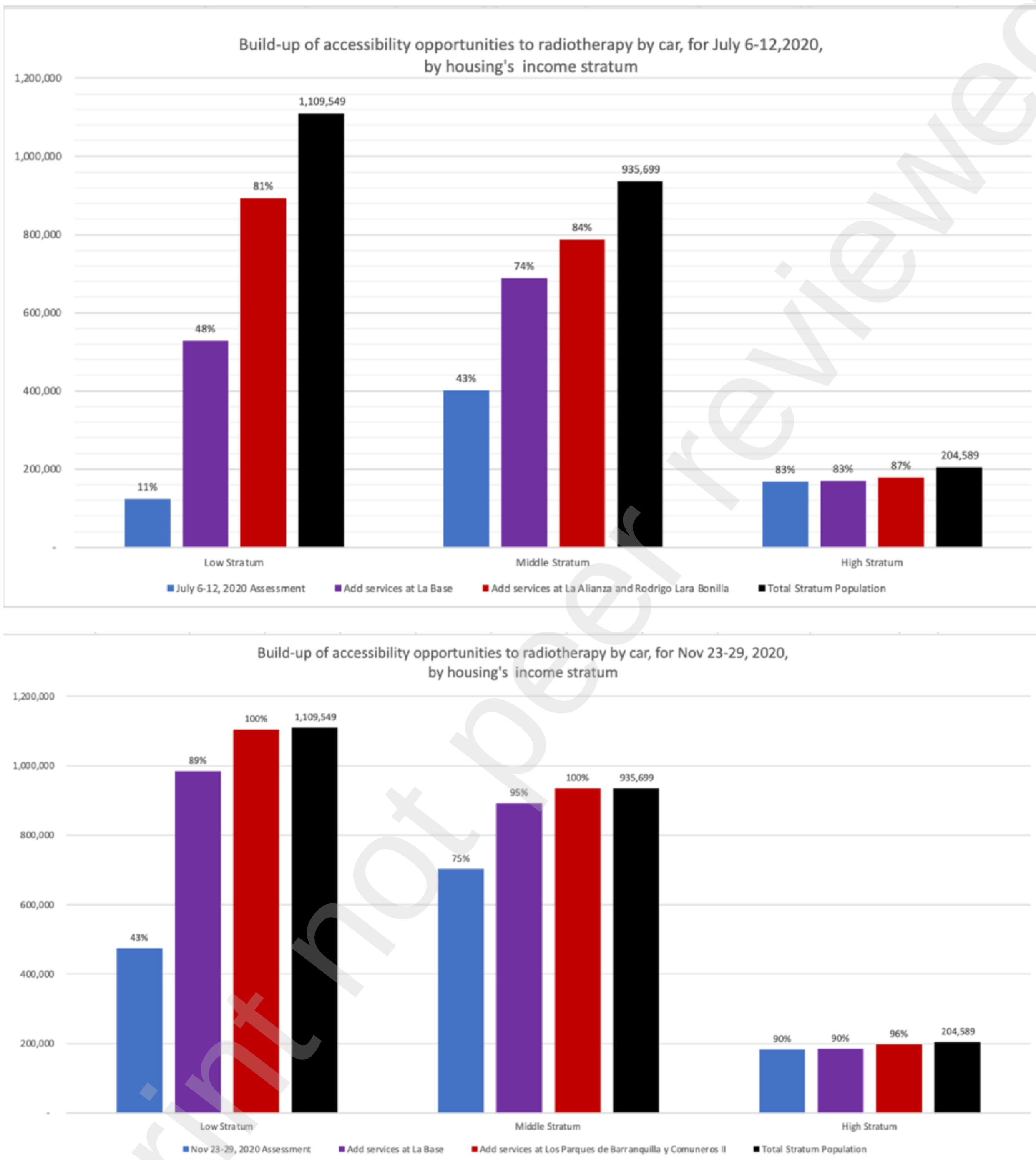


Figure 9. Assessment and predictions for accessibility improvement by housing income stratum for two measurements: July and November 2020

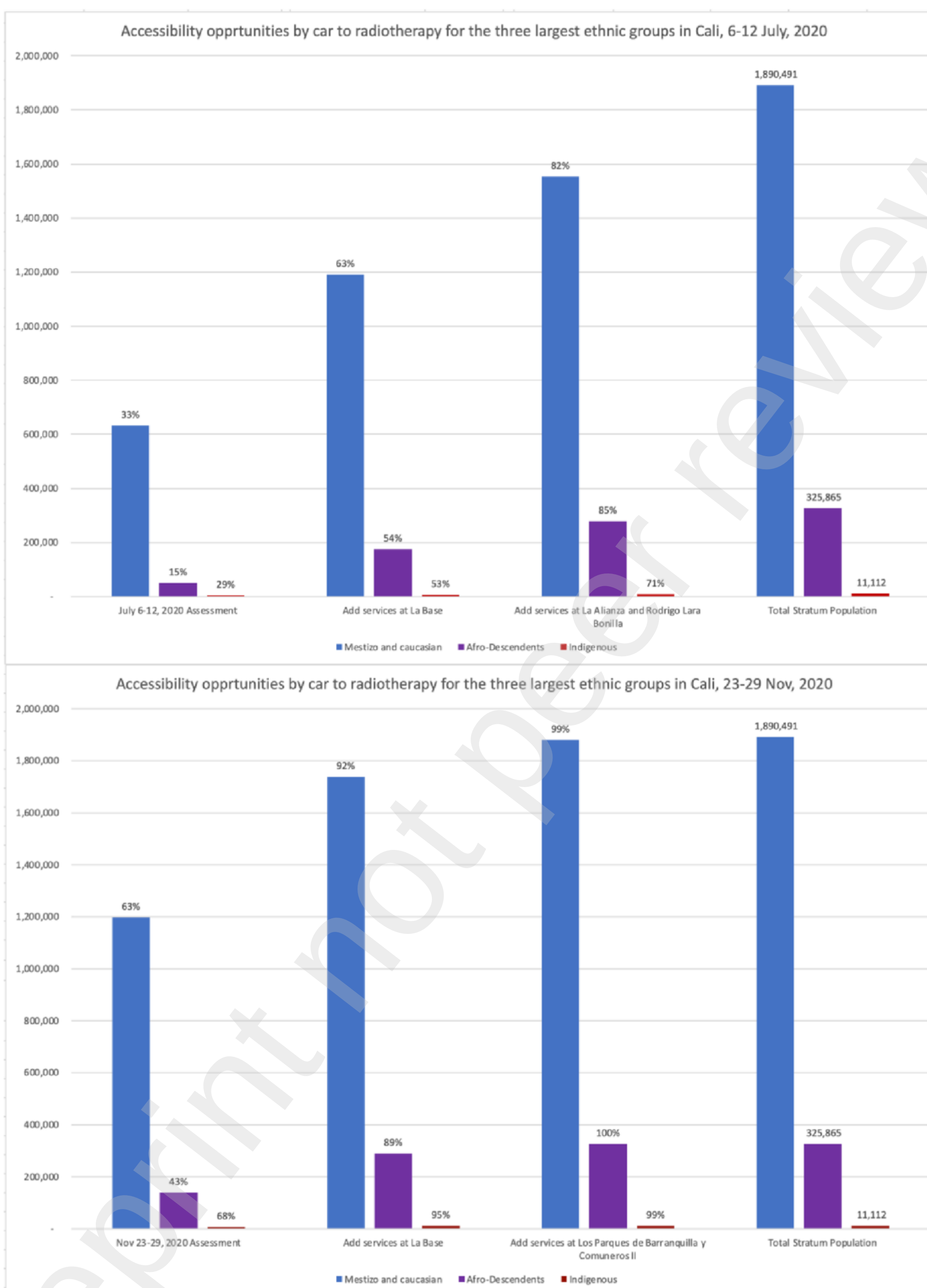


Figure 10. Assessment and predictions for accessibility improvement for the three largest ethnic groups in Cali: July and November 2020

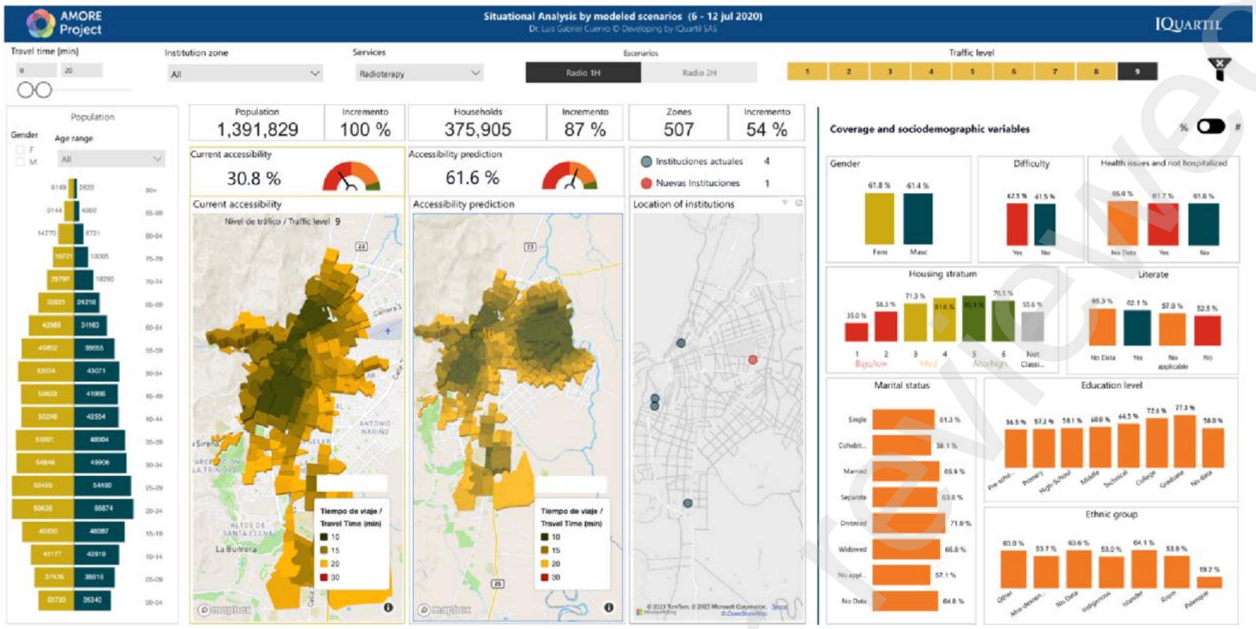


Figure 11 Interface with the relative effects of adding services in a location per July data

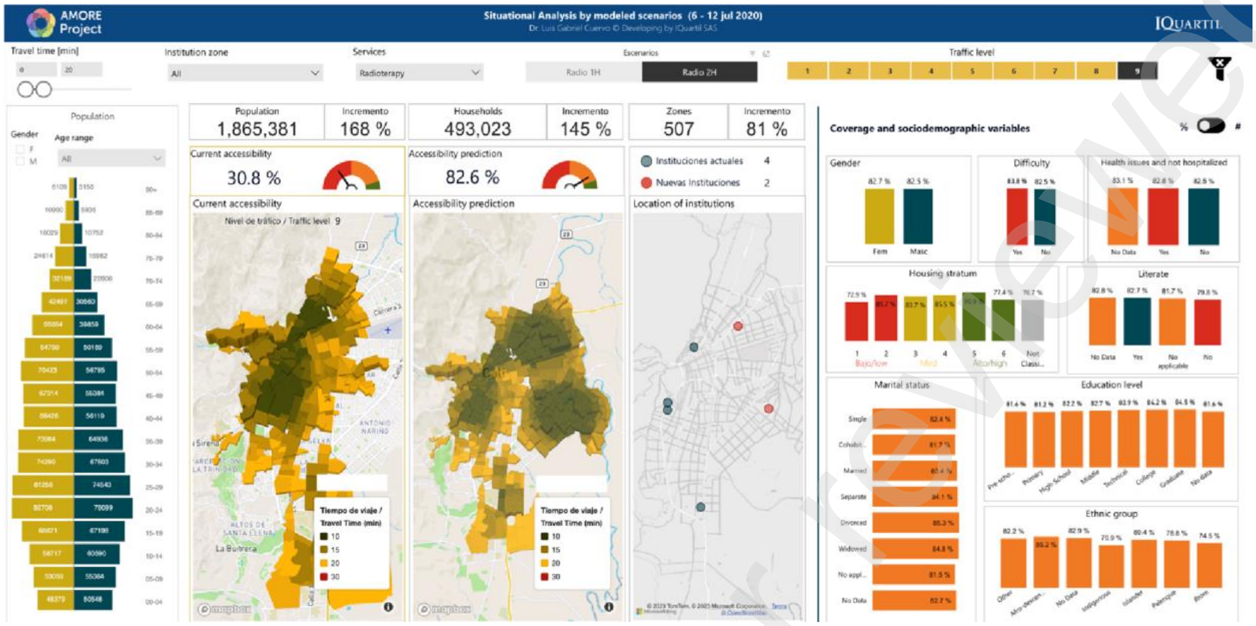


Figure 12 Interface with the relative effects of adding services in two locations per July data