C2DB:

Crowdsourcing to Identify Digital Gaps and to Estimate the Cost of Bridging those Gaps

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Abstract

Uncertainty in measuring digital gaps is a major obstacle that prevents the extension of digital connectivity in rural areas. This document describes a new methodology that, through crowdsourcing,[1] yields reliable, precise, and timely estimates. The C2DB[2] project (Crowdsourcing for Digital Connectivity in Brazil) was a technical collaboration between the IDB Group and the National Telecommunications Agency (ANATEL) that took place between April 2021 and March 2022, proving that crowdsourcing can complement the regulatory toolkit by providing accuracy, completeness, and timeliness in the geographical location of the demand and supply of digital connectivity in rural areas. The developed methodology helps to define the population base and service area, which in turn reveals gaps in coverage of fixed, mobile, and institutional broadband services. This helps to estimate the investment and economic impact of bridging the gaps, as well as the public contribution necessary for private investment to be profitable.

[1] Crowdsourcing: Anonymized information on the connections of end user terminals to broadband communication networks, whether mobile or fixed.

[2] C2DB was financed with funds from IDB Invest and the IDB's Connectivity, Markets, and Finance Division, and was formalized with Technical Cooperation Agreement No. 10/2021 between ANATEL and the IDB Group.

Introduction

Access to broadband services is vital for the knowledge-based economy and indispensable for new business models characterized by disintermediation, sharing, and online collaboration.[3] For the past decade, many studies have related the increase in population access to broadband services with economic growth.[4] Recently, other studies have related it with positive cross-cutting effects, such as the reduction of CO_2 emissions,[5] the education of women and girls,[6] and the productivity of sectors such as agriculture, transportation, and energy distribution.[7] Broadband expansion means deploying more infrastructure, capabilities, and network services, which creates jobs for all types of companies, from large multinational Mobile Network Operators (MNO), infrastructure builders, and national solution integrators to small regional broadband service providers (small scale suppliers, or SSS).

Several international organizations have studied the digital gap.[8] In 2020, the OECD published a study of the telecommunications market in Brazil. The study reported that, although Brazil looks good compared to other countries in the region, when compared with OECD, Brazil achieves only 50 percent of fixed and 80 percent of mobile broadband services penetration.

The National Telecommunications Agency (ANATEL) is the counterpart in Brazil and the source of much of the data used in the digital gap analysis carried out by international organizations. As the sector's regulatory body, ANATEL studies the population coverage of broadband services and the presence of fiber optic transport network infrastructure for data transport at the municipal level (Municipal Backhaul[9]) and updates the level of economic competition in broadband markets, among many other functions and responsibilities.

[3] Second update of the institutional strategy (IDB AB-3190-2).

[4] According to an analysis of the IDB 2012 and IPEA 2017, a 10 percent increase in broadband services penetration is associated with estimated average increases in gross domestic product (GDP) ranging from 0.77 to 3.19 percent.

[5] Telefonica 2020.

[6] Women and The Web, Intel 2012.

[7] IHS Markit 2019, in an estimation of the potential contributions of 5G technology to economic sectors; GSMA 2020, in a study of the contribution to compliance of millennium goals.

[8] The IDB index IDBA measures the development of broadband in the region.

[9] Included in the PERT and in the index of the ABEP-TIC.

The IDB has been studying the development of broadband in Brazil since 2019, analyzing the application of crowdsourcing to the evaluation of the coverage of broadband services,[10] to the monitoring of the use of the radio spectrum,[11] to the evaluation of the digital gap, and to the estimation of the cost of bridging the gap, these being C2DB's objectives. In 2021, the IDB conducted studies in collaboration with the Ministry of Communications (MCOM) to analyze access to credit and the tax burden of the thousands of SSSs that together contribute to 40 percent of fixed broadband access in the country[12] and provide services to many rural areas.

Knowing the geographic location of the demand and supply of broadband services is important for contracting services, developing infrastructure, designing public policies, and regulating digital connectivity.[13] The challenge of universalizing digital connectivity increases as it becomes more widespread and diversified. It is possible to channel other critical services such as education and health through digital connectivity, creating new sector gaps as these sectors advance in their digital transformation processes.

The universalization of digital connectivity requires large investments, and more countries are recognizing the need for public-private partnerships (PPPs) to meet this challenge.[14] The private sector requires a regulatory framework and conditions to allow mitigating uncertainty regarding projected revenue flows, as well as to keep operating costs as low as possible in order to make business cases viable. On the other hand, the public sector requires accuracy in defining the eligibility criteria for public policies and the speed to adapt those policies to the dynamic development of the sector.

[10] Municipal Digital Connectivity Index (ICDM), part of the Economic and Sector Work ESW RG-E1613 of 2019.

[11] Spectrum Usage Model (MUE) of 2020 and Really Efficient Award & License (REAL5G) of 2021.

[12] ANATEL's Data Panel.

[13] By digital connectivity we mean both the retail market for broadband internet access communication services (mobile [SMP], residential [SCM], and business, among others) such as the wholesale market (access to network infrastructure, capacity, and services, high-capacity data transport networks, hosting facilities, interconnection and service management, as well as access services to radio spectrum frequency bands in sec mode).

[14] We mean public support programs for the development of digital connectivity infrastructure by the private sector in countries such as Australia, the United States, and New Zealand.

The accuracy, completeness, and timeliness of the geographic location of the demand and supply of broadband services is particularly important when analyzing rural areas of low population density. The accuracy of socioeconomic information is available at the municipal level or by census sector, which can result in inaccuracies both in the location of demand and in the sizing of the infrastructure needed to meet it, since large geographic areas and small populations in rural areas are involved. At the same time, accurate information on demand and the location of existing telecommunications service coverage is important for the efficient use of financial resources in the design of connectivity infrastructure projects, particularly in rural areas. These inaccuracies in available information may affect the reliability of economic models that assess financial and social returns in rural areas.

The completeness of geographic location information on the demand and supply of fixed broadband services is affected by the fragmentation of the sources of information received by the regulatory body, since they come from thousands of operators offering their services in different parts of the country, which is affected by the size of Brazil. This situation is further complicated by the fact that the details of the information that operators report depend on their regulatory classification, which does not make many of the SSSs serving rural areas[15] report their service coverage.

In the case of the mobile market, it is common to estimate the supply of services based on the geographic location of antennas, calculating coverage based on wave propagation models.[16] The regulatory body receives service coverage projections from mobile operators and verifies some areas specifically, for information control purposes and by conducting field measurements (drive tests). These field measurements provide accurate and reliable information but are rarely carried out in rural areas due to the investment of human and material resources involved. The situation is further complicated by the increasing diversification of frequencies and antenna types, which makes coverage projections more complex.[17]

[15] According to data from ANATEL, thousands of small scale suppliers (SSSs) are responsible for more than 40 percent of the country's residential broadband access, with a large presence outside urban areas.

[16] ITU 2008, Telecom Network Planning for evolving Network Architectures. Reference Manual. NPM/5.1 (https://www.itu.int/ITU-D/tech/NGN/Manual/Version5/NPM_V05_January2008_PART2.pdf)

[17] 3GPP TR 32.835 V12.0.0 (2014-06) 3rd Generation Partnership Project (3GPP) Study of Heterogenous Networks Management (Release 12)
https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=2241

On the other hand, the difference between the regularity of the sources of information provided by the public and private sector creates additional inaccuracies in the elaboration of economic and financial models. The telecommunications market is dynamic, and differences in the time horizons of the data used in the planning phase and the deployment and operation phases of connectivity infrastructure projects may generate divergences between the expected results and those obtained in practice, increasing uncertainty. These divergences may also impact public functions, such as the supervision of obligations and the coordination of programs, whose complexity increases as more spectrum is made available to the private sector and the productive and social sectors move forward in their digital transformation processes.

There are, therefore, incentives to obtain timely information on the geographic location of the demand and supply of broadband services, to identify causes, effects, and trends and take preventive actions to mitigate risks. As more data is generated and analyzed, it is possible to predict the outcome of actions and decisions in the public and private sectors.

The need to obtain and make available accurate, complete, and timely data on the geographic location of demand and supply in retail broadband service markets to industry players will be accompanied, in the short term, by the need to localize access to wholesale inputs, such as shared telecommunications infrastructure,[18] and frequency bands available for secondary use.[19] The solution proposed herein is to contribute to complement the current toolkit for the geographic localization of the demand and supply of fixed, mobile, and institutional broadband services through new techniques based on the use of crowdsourcing, with the following objectives: (i) improve accuracy in rural areas; (ii) complete information independently of regulatory considerations; (iii) monitor evolution in a regular and timely manner; and (iv) identify the digital gap, estimating the cost and developing tools to bridge it.

[18] ANATEL's national system for negotiating wholesale bids SNOA.

[19] Law 13879, which provides for the secondary use of the radioelectric spectrum.

Methodology

Private initiative has been using crowdsourcing to analyze broadband services since the middle of the last decade. With the popularization of smartphones, companies such as OOKLA, Tutela, and OpenSignal emerged, specializing in aggregating the technical data of user connections to broadband networks and making it, anonymously, available to operators, providers, and other players in the telecommunications sector as support for the design, operation, and marketing of broadband telecommunication networks and services. These large data collections store two types of data: (i) data automatically generated by smartphones when they connect to mobile networks, which are able to identify connection data such as technology, service provider, and frequency band used, as well as some technical parameters that allow inferring service coverage;[20] and (ii) tests initiated by end users wishing to test the quality of their connection, which saturate the communication channel to identify the performance in terms of speed and latency.[21] Access to crowdsourcing data is acquired by companies with telecommunication sector knowledge and geographic processing and data analytics capabilities to conduct specific analysis. The new release of initiatives such as ESRI Telecom and META Connectivity is an indication of the increasing democratization of this type of analysis by the private sector. Recommendation UIT-T E.812, which the International Telecommunication Union (ITU) published in 2020, discusses the application of crowdsourcing in assessing the quality of broadband services, endorsing the adoption of crowdsourcing in the regulatory environment.

C2DB work was divided into a technical and financial part. The technical part was directed toward locating the broadband coverage gap in rural areas through crowdsourcing and estimating the cost of bridging the gap, while the financial part was directed toward estimating the proportion of public and private resources that would be required to bridge the gap while complying with financial market fundamentals. Different steps are summarized below. (More details can be found in the specific technical reports for the technical part and for the financial part.)

[20] We mean the parameters that measure the strength and quality of the signal received from the base station (OOKLA).
[21] These Speedtest tests measure downstream and upstream data transfer speed, latency, and jitter.

First, the population distribution and socioeconomic information to be used were identified. The High Resolution Settlement Layer (HRSL) was used for population distribution, and the population was adjusted to IBGE projections available at the census sector level for the year 2021. The 30-meter resolution of the HRSL works well for rural areas, allowing increase of analysis accuracy with respect to that offered at the municipal or census sector level. In the case of socioeconomic information, databases were acquired with projections of per capita purchasing power and number of people per household, to the year 2021, prepared by MB-Research, at the census sector level.[22]

The next step was to identify, through crowdsourcing, the aggregate coverage of both mobile and fixed broadband services. For this purpose, a consulting firm was contracted[23] with access to both types of crowdsourcing data and asked to provide a number of data processing and analysis services specified in the terms of reference.[24] One of the first specified steps was to curate six months of nationwide crowdsourcing data and to organize it into a geographic analysis framework based on Geohash 7 (GH7), whose granularity of 150 m by 150 m is consistent with that of the 30 m by 30 m population distribution of the HRSL. Next, the data that were automatically generated by mobile terminals was used to validate the population base according to mobile coverage provided, obtaining population coverage values consistent with the official ones,[25] while the aggregate coverage of fixed broadband services was made from user-initiated speed test data, as there is no other basis for comparison.

Then, population and coverage results at the GH7 level were enriched with socioeconomic data and the location of points of interest (in this case, schools and public health facilities), aggregating the resulting information at the Geohash 6 (GH6) level. The GH6 geographic aggregation level of 1.2 km by 600 m was selected for two reasons: (i) It is comparable to the resolution of both mobile and fixed service coverage offered by wireless access networks; and (ii) it represents a good compromise between processing needs and accuracy of results, allowing the creation of more accurate population coverage in rural areas. Public school and health facility databases and road and waterway right of way paths were curated from different sources[26] and mapped for use in the connection phase.

[22] The socioeconomic information at the census sector level was the one with the most capillarity available.
[23] EFTS Group.
[24] Terms of Reference available in Technical Cooperation Agreement No. 10/2021.
[25] Population coverage of crowdsourcing was 0.85 percent higher than ANATEL's coverage projection.
[26] Official sources: Fundação Lemann and Open Street Maps.

From this point on, when the empirical information on population, points of interest, and broadband service coverage have been updated, mapped, and structured at a GH6 capillarity level, the analytical phase can begin. In C2DB, the analytical phase took the 2.3 million GH6 resulting from the population base, points of interest, and service coverage with the purpose of locating the digital gaps in fixed, mobile, and institutional broadband services and, from that point on, estimating the cost of bridging the gaps and the volume of public and private investment required to achieve their financial viability. It should be noted that, once the information base has been developed in GH6, the possibilities of the analytical phase are expanded.

To carry out the gap analysis, the lack and abundance of digital connectivity were identified. On the other hand, in order to locate the lack of connectivity, 1.7 million GH6 were located with total or partial absence of 4G mobile or fixed broadband service coverage, where 19 million people live, and 586,000 GH6 were selected among them with the capacity to increase population coverage of broadband services from 90.7 to 98.2 percent,[27] establishing this last percentage of population coverage of broadband services as a target to estimate the cost of bridging the gaps. These 586,000 GH6 were called BBAs (basic broadband areas), and were grouped geographically around public schools, using the criterion of proximity.[28] Public schools were selected because they have a wide geographic distribution nationwide and because of the beneficial impact that improved connectivity has on the education of children (the future of society). In the next iteration, BBA aggregating schools were connected to each other through the previously mapped rights of way, defining a local data transport network architecture referred to as a "cluster," whose main node was referred to as the "cluster head." Some 26,000 clusters were thus identified at the national level, which grouped together all the BBAs.

[27] The population coverage target of 98.2 percent corresponds to the highest regional median of population not covered by GH6: 7.7, which is equivalent to a population not covered by broadband access services of 10.7 people per km^2.

[28] The aggregation of BBAs around public schools was based on Euclidean distances and the weighting of three factors: distance, population, and context. This first level of aggregation did not consider orography, type of terrain, or existing rights of way. More information on the BBA aggregation algorithm in public schools can be found in the following documentation (Final_report_cd2b.pdf). There are other ways to add BBAs around points of interest.

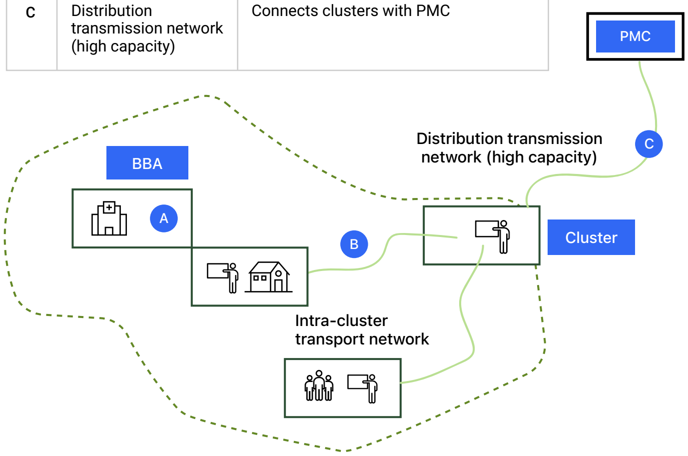
To locate the abundance of connectivity, this study used points with documentary evidence of robust digital connectivity[29] to identify the characteristics of crowdsourcing data where there is certainty of good connectivity conditions. Then, that characterization was used to infer 2,330 points of maximum connectivity (PMC) nationwide, which can be considered potential access points to the national data transport infrastructure. Inferring the location of PMCs does not replace the documentary evidence of telecommunication infrastructure location maps provided by operators, which are the most reliable source of information for locating digital connectivity infrastructure but are affected by the challenge of having complete information as described in the introduction. Once the unmet demand clusters and the PMCs were located, they were connected by means of previously curated rights of way.[30]

[29] Sites such as 4G towers, interconnection points, and points of presence of data transport networks were used.

[30] In the absence of rights of way, alternative microwave links, including satellite links, were considered.

Infographic 1. C2DB Project: General Concepts for Cost Estimation

	Network level	Description
A	Access network layers	Three separate access networks: mobile, fixed, and institutional
B	Intra-cluster transport network	Connections between aggregation schools belonging to the same cluster
C	Distribution transmission network (high capacity)	Connects clusters with PMC



BBA (broadband area): Minimum area of analysis (a GH6, 1200mx600m) containing broadband services unattended demand:

- Population
- Homes
- Institutions
  - Public health units
  - Public schools

580,000 BBAs

Cluster: A group of BBAs gathered around a cluster hub, which is the best located public school to groom traffic and route it to the most appropriate PMC. Larger clusters include data network links within the cluster.

26,000 clusters

PMC (point of maximum connectivity): AI-inferred location with optimal connectivity conditions. Each cluster is connected to the nearest PMC using high-capacity transport network links.

2,330 PMCs

Once the clusters and PMCs have been located and the connections between them have been proposed, the costs of serving them can be estimated. For this cost estimation, an access part and a transport part were considered. The access part assessed three separate access networks, one for residential fixed services, one for mobile services, and one for points of interest.[31] The transportation part was assessed in common, considering two levels: The first intra-cluster level estimated the cost of connections between aggregating schools within a cluster, and the second "high-capacity transportation" level estimated the cost of connections between cluster heads to PMCs.[32]

[31] Cost data was based on ANATEL's cost models and regional references provided by the IDB. Costs were considered for 4G wireless access networks in mid-band mode FWA for fixed services and in low-band MBB mode for mobile services. The costs for the points of interest were based on fiber optic cable connections in point-to-multipoint and point-to-point configurations, according to the network model hierarchy used for the demand aggregation exercise. The estimation was budgetary, based mainly on the comparison between service areas and coverage areas. An improvement in the methodology for future exercises would be to use access network planning tools that consider orography, topography, terrain types (Clutter Maps), and rights of access, as well as more detailed information on the presence of existing infrastructure that could be reused.

[32] In connection and cost, the use of road and waterway rights of way was favored; if these connections were not possible, Euclidean distance assumptions were considered for microwave links (up to three links in a path, each with a maximum of 10 km) and satellite links for longer distances.

Based on the investments, operating costs were estimated[33] and, by comparing purchasing power[34] and average service prices,[35] additional subscribers were estimated and, from that point on, revenue streams and economic impact[36] were estimated. Average price of services was researched at the municipal level and the economic impact was estimated based on references obtained from a review of the available literature on the economic growth derived from bridging the fixed, mobile, and institutional connectivity gaps.[37] These results were the main input for the financial part.

On the financial side, a specialized company was hired[38] to consult with Brazilian industry operator associations on their preferences regarding types of services, project sizes, and structuring/contracting models, and with these inputs proceeded to develop an economic and financial model to calculate what the target public contribution should be for private resources to be incorporated as part of the investment and the internal rate of return would equal the weighted average cost of capital, at the PMC, state, and regional levels.[39]

Private players contacted agreed in their comments on the main characteristics of potential projects: (i) allow fixed and mobile connectivity for subsidized projects, (ii) consider the state dimension for the definition of the size and scope of the projects, and (iii) favor the private DBO model[40] as the PPP model to be followed.

[33] Annual operating costs were estimated based on percentages of infrastructure investments, using data from ANATEL's cost models and regional benchmarks as a reference.

[34] We used the household budget data from the IBGE.

[35] Average prices for services were researched online and reported at the municipal level.

[36] Summary of economic estimates Mark Kennet 2021. The base case for estimating additional subscriptions was ANATEL's projections made for the 5G frequency tender, over a five-year horizon.

[37] In order to make these considerations, traffic per service was estimated and projected and the population's capacity to acquire the services was considered based on their purchasing power compared to prices.

[38] Deloitte Spain.

[39] Presentation of financial C2DB results.

[40] Model of Private DBO: The model involves a private sector organization receiving some level of public funding (often a grant) to assist in the deployment of a new network offering open wholesale access. One observation to this model is that the public sector has no specific role in the ownership or operation of the network, although it can impose obligations relating to either in exchange for funding.

Analysis of Results

For the analytical part, the paper identified almost 20 million Brazilians living in areas where no evidence of broadband connectivity was found and estimated that extending broadband service coverage to the 16 million living in one-third of that area would increase population coverage by more than 7 percentage points, triggering gross domestic product (GDP) growth by 2.4 percent[41] and it would cost USD 9.5 billion, of which almost two-thirds would be a public contribution to make it financially viable.

The financial analysis of the 2,330 PMCs showed that 10 percent would be profitable and would not need to receive public funds, while 90 percent would require public funding to a greater or lesser extent, namely: (i) 14 percent of the total (mostly located in the central and south regions) would require public support of less than 30 percent of the investment, (ii) 45 percent (distributed in all regions) would require public support of between 30 and 70 percent of the investment, and (iii) 30 percent of the PMCs (located mainly in the north and northeast regions) would require public support of more than 70 percent of the total investment (the last 1 percent of the PMCs, located in the north region, would not generate acceptable returns even if the total investment was subsidized). Table 1 summarizes the estimated public and private contribution in the financial part.[42]

Table 1. Summary of the Economic and Financial Model

	South Region	North Region	Central West Region	Northeast Region	Southeast Region	PMC 0 (satellite)	Total
Public contribution							
Public contribution (%)*	46.40%	75.34%	61.26%	64.37%	52.07%	98.33%	**57.21%**
Public contribution (thousands of USD)*	391,241	1,582,443	233,217	2,446,861	800,889	669,148	**6,123,799**
Returns							
Project IRR after taxes	9,30%	9.30%	9.30%	9.30%	9.30%	9.30%	**9.30%**
Shareholders IRR	10,07%	9.28%	9.89%	10.05%	9.94%	9.66%	**9.93%**
Operating results (thousands of USD)							
Capex	1,128,714	1,865,500	432,129	3,591,934	1,817,208	680,384	**9,515,869**
Opex	634,091	1,209,499	245,983	1,722,892	941,229	90,914	**4,844,608**
Income	3,388,877	2,144,754	981,624	5,931,364	4,614,957	151,954	**17,213,530**

Source: Authors' elaboration.
*The results shown for "Public Contribution" do not include PMCs that do not require public funding to be profitable on their own.

[41] Documentation for Demand, Impact, and Projection Models M Kennet.

[42] The PMC 0 satellite project, considered for the most remote cases, can be undertaken as a special project, since it requires public funds to reach 98 percent of the investment.

The project generated a large amount of information, including tables, documents, presentations, and geographic display panels, available through ANATEL. Throughout the one-year process, several areas for improvement were identified in the methodology used, including: (i) using a finer granularity to locate broadband service gaps in urban, highly populated environments;[43] (ii) comparing broadband service coverage information from crowdsourcing with other sources of regulatory information;[44] (iii) establishing programs to ensure regular updating of broadband service coverage information through crowdsourcing; (iv) developing tools that allow not only to consult the data developed by C2DB in a rapid manner but also to facilitate an analysis based on the population and coverage base, automating the grouping of the demand[45] and the analysis of specific areas of interest;[46] (v) researching the possibilities of crowdsourcing to support the regulation of wholesale telecommunication markets; (vi) including more rights of way such as subnational road infrastructure or electricity distribution infrastructure in order to improve connection possibilities; (vii) improving and automating the cost estimation exercise based on national benchmarks;[47] (viii) supporting the creation of financial mechanisms to support the private sector that develops connectivity infrastructure in rural areas; and (ix) adapting the methodology developed to identify connectivity gaps in other productive and social sectors, such as agriculture, transportation, energy, health, and education.

[43] The GH6 granularity becomes larger than some urban census areas.

[44] Other regulatory information includes radio propagation projections, coverage verification and quality of service of the drive-test type, the use of probes for spectrum and traffic monitoring, the collection of data from network management systems, and surveys.

[45] Clustering of unmet demand could be done automatically around different points of interest or based on proximity to available rights of way.

[46] These points of interest would be geographic data sets (lines, points, areas), which the user could upload to know the coverage of broadband services.

[47] This is particularly interesting as new bands, technologies, and applications are implemented.

Conclusions

Crowdsourcing can be used to estimate with accuracy, completeness, and timeliness the geographic location of demand and supply of broadband services. And, from that base of millions of GH6 containing empirical information on the demand and supply of broadband services on, a multiple analysis is possible. The study showed that it is possible to estimate the gaps in population coverage of fixed, mobile, and institutional broadband services and the cost of bridging the gaps, as well as to evaluate the percentage of public contribution needed to make them financially viable.

Specifically, it was concluded that covering 422,000 km^2 of areas with no evidence of broadband services **could increase population coverage from 90.7 to 98.2 percent, increasing gross domestic product (GDP) by 2.4 percent, at a cost of USD 9.5 billion**, of which almost two-thirds would have to be public contribution for the private sector to be financially viable under prevailing market conditions by the end of 2021.

The collaboration between the IDB and ANATEL on the application of crowdsourcing will be extended to telecommunication regulations. To this end, the A2IC (expanding and deepening information on connectivity) and C2CS (crowdsourcing to increase competition and access to the spectrum in Brazil) programs have been launched, which will analyze the application of crowdsourcing-based information to the study of economic competition in broadband service markets (PGMC) and the implementation of a secondary spectrum market (RUE).

Looking ahead, maintaining an updated and available population and coverage base with access to market players would be beneficial to the telecommunications sector in Brazil. In this way, the public sector could complement the regulatory toolkit and improve the design and evaluation of public policies. At the same time, the private sector could reduce information asymmetry between different market players and mitigate project risks by improving the visibility of access to essential inputs such as infrastructure, spectrum, and government incentives.

To this end, it is necessary to create a program that keeps the population and service coverage information base up to date, generates incentives for market players to improve it, and implements tools that allow market players to access and visualize data, for them to evaluate the level of coverage of their points of interest in an online and interactive environment. Market players include consumers, telecommunication service providers, subnational governments, and productive and social sectors (agriculture, energy, transportation, education, and health) interested in driving a transformation agenda that is key to Brazil's economic development and social inclusion in the 21st century.

Annex 1. Examples of C2DB Geographic Displays

Display is an important part of the geographic approach to data analysis. Part of the scope of the C2DB project was the development of geographic displays, which were made available through a portal presenting the project, the main findings, and the four displays produced.[48]

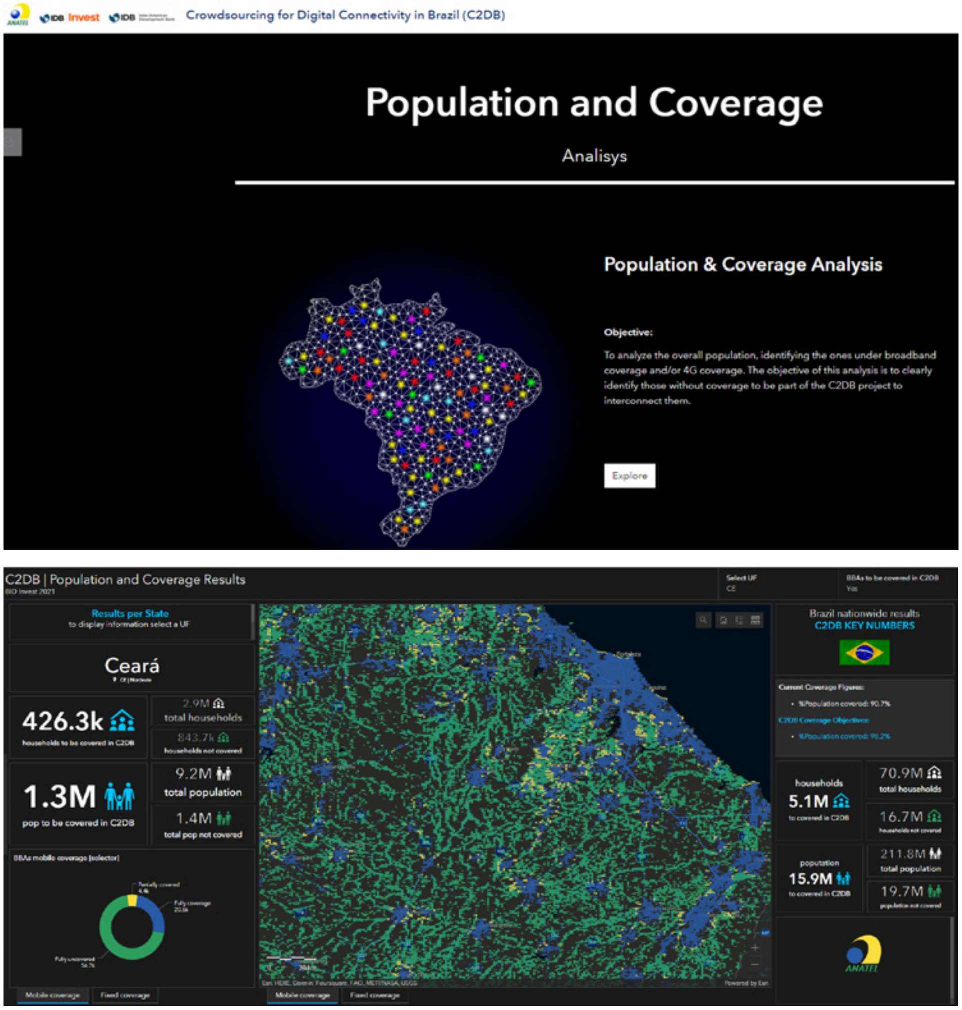
Image 1. The C2DB Project

The panels below illustrate part of the displays generated as part of the project. Panels 1 and 2 represent input data, where the population distribution and the empirical coverage of fixed and mobile services (Panel 1) and the distribution and coverage of the points of interest (Panel 2) are located. Panels 3 and 4 show the results of the analysis phase geographically, in particular the connection between the clusters of unmet demand and the identified points of maximum connectivity (Panel 3), and the estimates of the economic and financial model in terms of financial viability and public contribution (Panel 4).

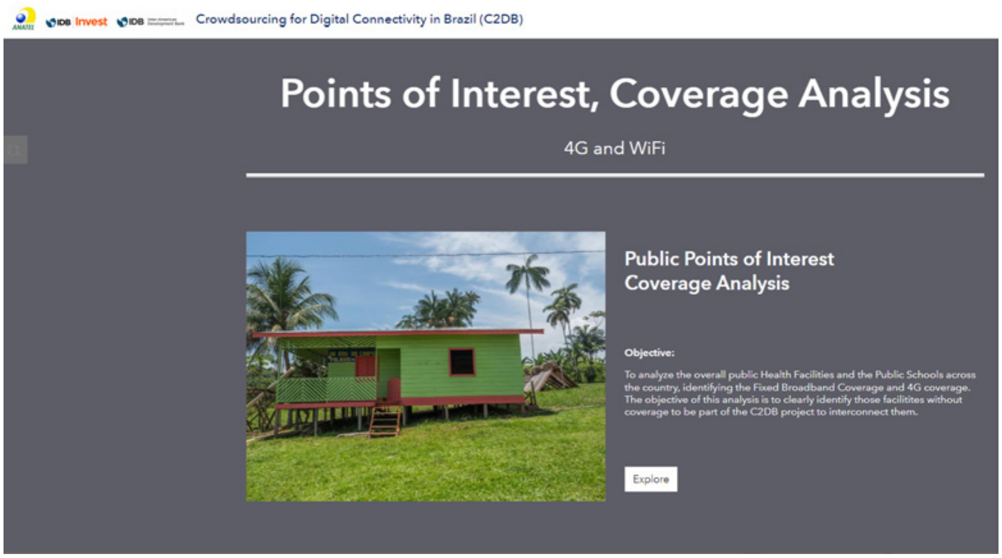
[48] Access to the portal and panels is possible through the intermediation of ANATEL.

These displays are just an example: A snapshot of the development of the sector in 2021, the beginning of the digital transformation of the gap analysis, and the definition of telecommunication projects and public policies based on empirical data.

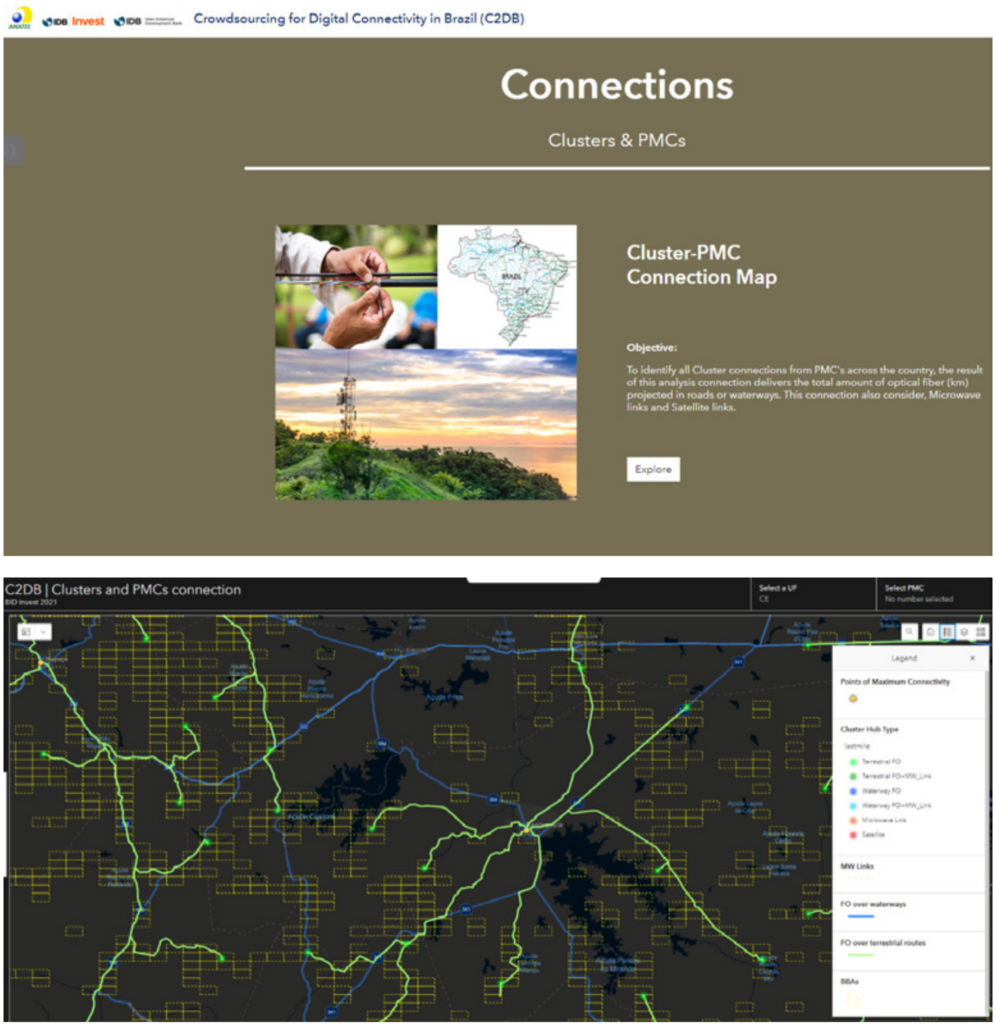
Panel 1. Population Distribution and Fixed and Mobile Service Coverage



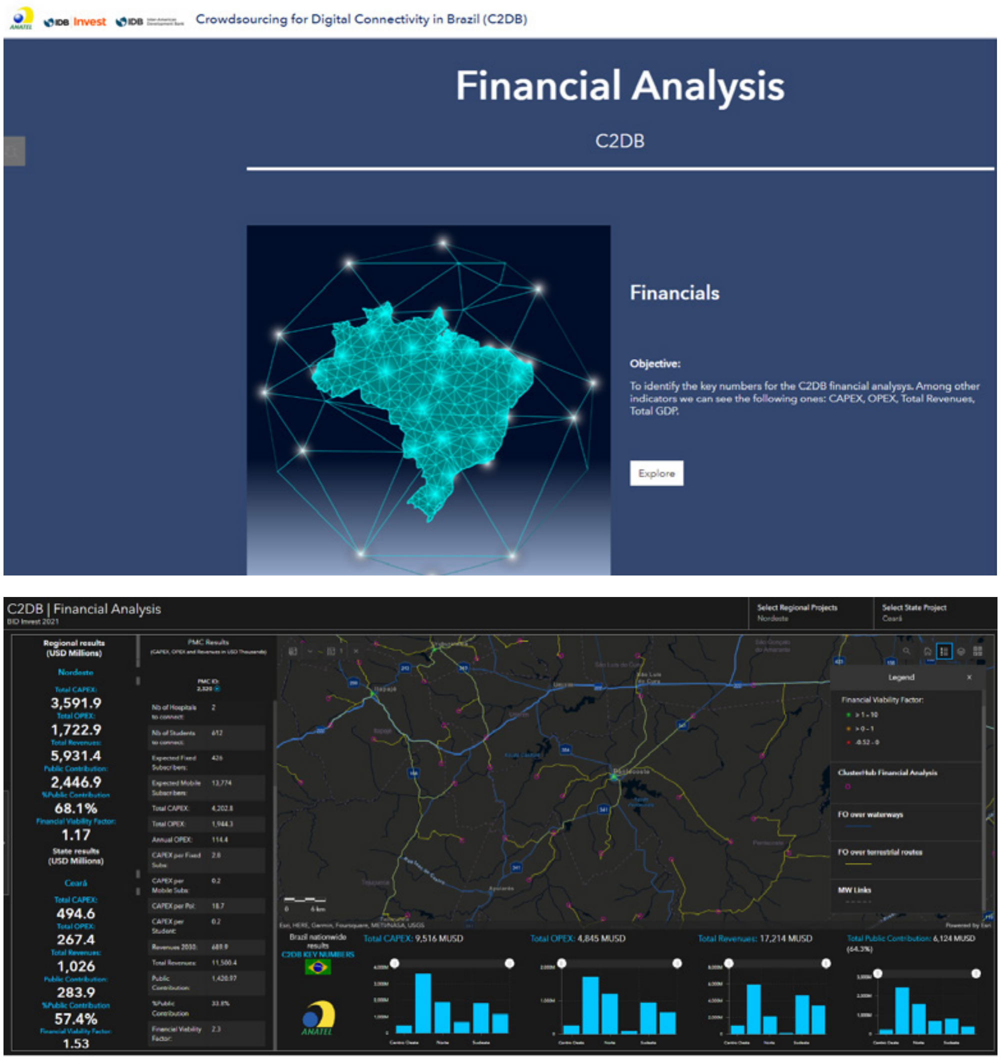
Panel 2. Location and Characteristics of Points of Interest



Panel 3. Points of Maximum Connectivity and Connections to Clusters of Unmet Demand



Panel 4. Geographical Presentation of Results of the Economic and Financial Model with Financial Viability at the PMC Level on a Color-Coded Basis



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