Bell Labs Consulting

Going the extra mile with BEAD intelligence: Project area and cost share optimization

White paper

Contents

The problem facing states – leaving no communities behind

Unserved and underserved communities throughout the United States are benefiting from a massive broadband transformation which will enable essential services such as remote education, telemedicine and remote work for people living in those communities while also creating jobs and stimulating e-commerce and industrial development. The introduction of broadband connectivity to these communities will spur the development of states and territories into vibrant digital economies that can serve the needs of people and businesses throughout the nation. In order to accomplish these objectives, states must overcome several challenges, as described below.

States must make optimal use of available funds to connect all unserved and underserved communities while ensuring affordability and economic sustainability.

Five-year action plans and initial proposals for the Broadband Equity Access and Deployment (BEAD) program have been submitted by states and several have already obtained or are expected to obtain approval from the National Telecommunications and Information Administration (NTIA) soon. State broadband offices are in the process of conducting challenge processes to refine their unserved and underserved location maps. They are also preparing to make broadband awards to internet service providers (ISPs) by focusing on the following actions:

1. **Defining project areas:** States need to carefully construct project areas based on geographic or demographically constructed boundaries that incentivize providers to participate with matching funds for broadband network deployments. For maximum flexibility, project areas may extend across county boundaries.
2. **Promoting competition:** It is important for states to promote competition in order to give broadband consumers the ability to choose providers. This will ensure higher service quality and drive more affordable access, which will as a consequence allow higher adoption rates. The advantage held by incumbent providers and the potential for states to promote competition is discussed in detail in a Bell Labs Consulting companion paper [1].
3. **Ensuring economic sustainability of broadband networks:** The success of broadband deployments will depend on the long-term economic sustainability of broadband network projects in terms of their revenue potential, cost of deployments, including fiber, optical network equipment and labor, cost of financing, and cost of operations. States must assess the economic sustainability of projects while defining project areas in order to determine the project area boundaries and/or the appropriate cost share.
4. **Establishing need for alternate technologies:** States need to establish an extremely high cost per location threshold (EHCT) for fiber projects in order to determine where alternate technologies such as fixed wireless access (FWA) or satellite access offer viable cost-efficient solutions relative to fiber broadband. This will ensure that the goal of covering extremely high-cost locations is satisfied with the available funds.

Achieving universal broadband with BEAD creates new challenges for states that have not been encountered or addressed through previous programs.

There have been a number of previous government-subsidized broadband deployments in the United States including those funded by the Rural Digital Opportunities Fund (RDoF), Connect America Fund (CAF), Broadband Infrastructure Program (BIP), Reconnect, Capital Projects Fund (CPF), and the American Rescue

Plan Act (ARPA). However, the situation faced by states today with BEAD is much more challenging on account of the following factors:

- **Previous programs were much smaller in scale** and the size and scope of deployments were limited to areas where providers were assured of a sustainable business case and were willing to participate.
- **Material and labor costs are now higher than most initial estimates.** Much of this increase in costs has been driven by inflation over the past few years [2]. Furthermore, the huge scale of the program will lead to a spike in demand for skilled labor that is expected to significantly drive up labor costs.

5. **There is significant variability in different regions of the country and even within each state** in terms of the terrain as well as the density of broadband serviceable locations (urban, suburban, rural), which impacts the ease of deployment, the mix of buried or aerial fiber, the prevailing labor costs, and the need for alternate technologies.
6. **To achieve universal broadband connectivity, there is now a need to connect all locations, not just the most attractive ones.** Every successive program is left with worse locations, resulting in economic sustainability no longer being guaranteed for providers with similar expectations on matching contributions.

There is a strong need for intelligent project area definition and cost share optimization to incentivize provider participation and ensure a level playing field across providers in terms of economic sustainability. Providers must be incentivized to cover all broadband serviceable locations with fiber (except perhaps the most expensive ones). Contributing 25% or more in rural areas with excessive costs per location is a daunting challenge for providers, especially in the face of uncertain adoption rates and limited revenues. Intelligent project area definition and cost share optimization can help mitigate this problem of economic feasibility by helping to optimize both cost share and project areas.

In order to achieve successful broadband implementation, it is important for states to understand the expectations on matching funds from providers and also the tradeoffs with respect to deviations from these expectations prior to conducting the sub-grantee selection process. For example, provider claims of in-kind cost share for prior or ongoing deployments will strain state budgets. With multiple rounds of application and/or negotiation, cost share expectations may need to be adjusted to connect unserved and underserved locations in each project area. This will especially be important to ensure the maximum availability of funds for deployments throughout each state as well as for any non-deployment programs (e.g., training, workforce development, device and service subsidies) envisioned to spur broadband adoption.

Providers will need to conduct independent studies to assess their potential for matching contributions considering their own individual financial situation, revenue potential and costs of candidate project areas, incumbency advantage for claiming "in-kind" cost share, or the possibility of revenue and/or cost-sharing with other providers.

In this paper, we describe how connectivity to unserved and underserved communities can be maximized by optimizing the economics of broadband project areas (i.e., cost subsidies and area definitions). We first consider project areas defined by the state based on strict geographic and demographic constraints. We then investigate a novel technique for project area definition to achieve a level playing field in terms of broadband economics among service providers attempting to provide connectivity across disparate distributions of broadband serviceable locations.

Here is a summary of our key findings and recommendations:

1. With rising deployment costs and increasingly rural locations, states no longer have the luxury of picking favorable locations that offer an attractive business case to providers.
2. Broadband deployments must be economically sustainable and provide equitable and affordable access to consumers.
3. Project areas must be carefully constituted using a clustering approach designed to minimize the number of serviceable locations while ensuring revenues for economic sustainability.
4. The discounted payback period serves as a good measure of internet service provider profitability and economic sustainability of broadband networks.
5. By establishing a target discounted payback period, the subsidy from the state and the corresponding service provider investment needed may be optimized for each cluster (or project area).
6. Project areas may be optimized by combining contiguous clusters to reduce the variance in payback periods as well as service provider matching investments; the number and size of designated project areas may be used to promote participation by regional providers.
7. The state should leverage cost-sharing arrangements and designate specific geographies where service providers can compete effectively to achieve a level playing field in terms of service provider participation and profitability, which will support the BEAD program's goal of maximizing connectivity to unserved and underserved locations.

Maximizing connectivity by optimizing economics of broadband project areas

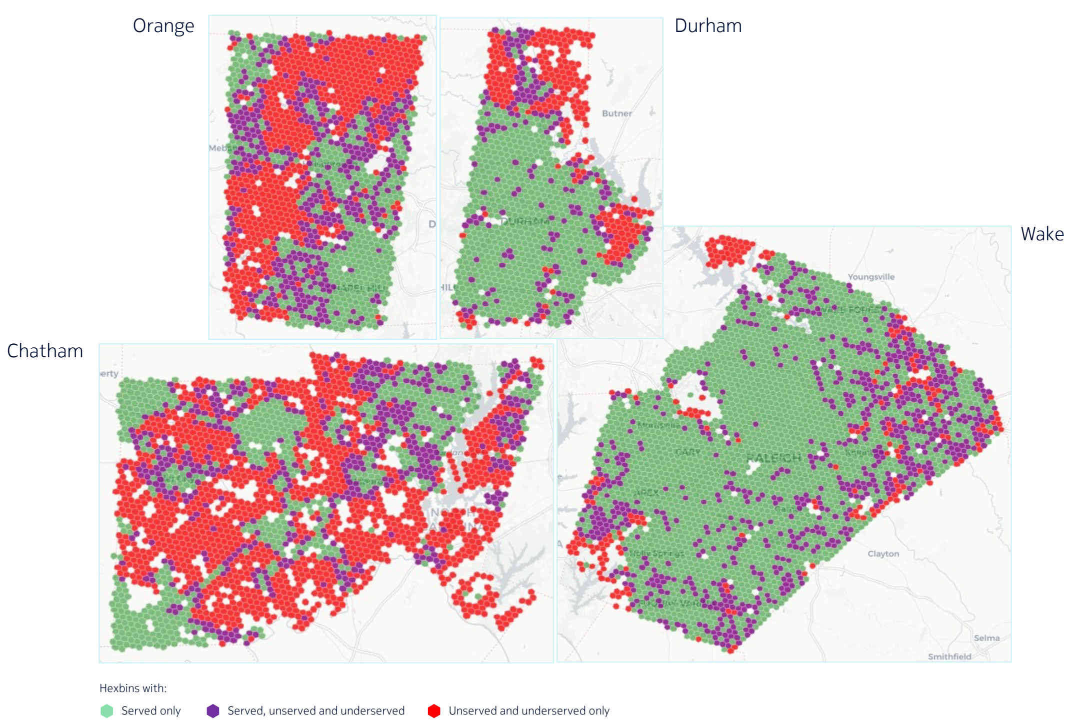
Project area definition based on clustering

States often determine project areas based on geographic and/or demographic criteria. This could result in project areas being determined based on county boundaries, census tracts, or census blocks. These definitions provide a basis for determining the optimal fiber optic network design and the associated cost of building and operating these fiber networks.

One approach is to designate counties as project areas. However, while counties are appealing as geographic entities for local governance, they are not necessarily well suited to serve as fiber network project areas. For instance, large counties may preclude bids from smaller operators that lack the physical presence or financial resources to cover them in their entirety. Moreover, unserved and underserved areas often extend across county boundaries, and it is better not to artificially subdivide these areas and reduce their appeal for new entrants.

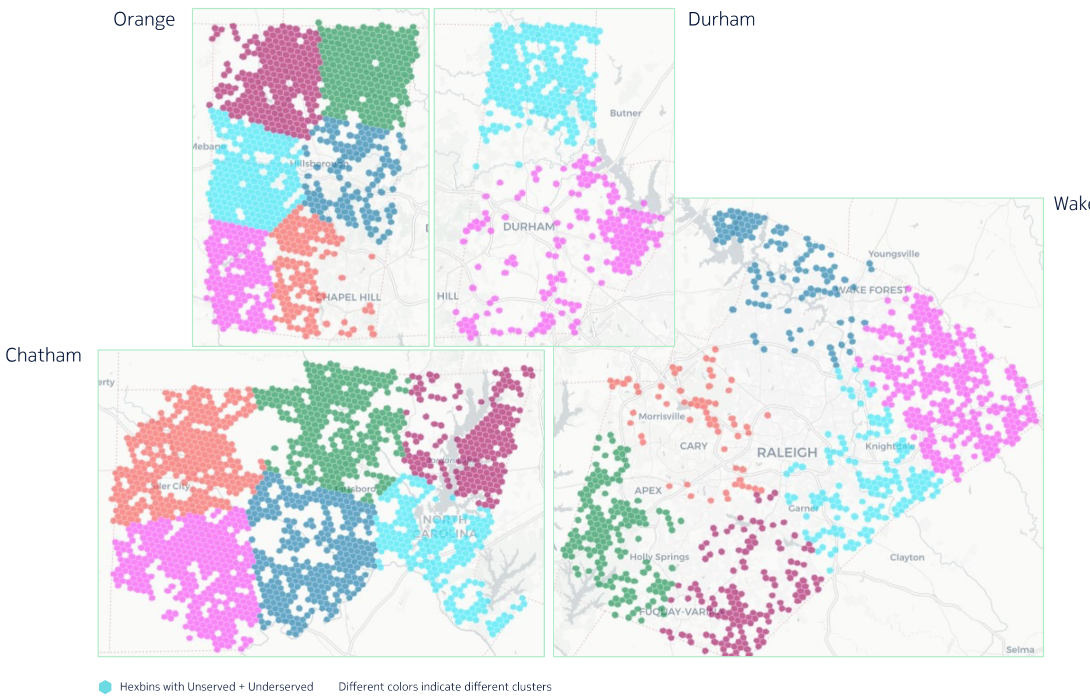
In what follows, we introduce a more general concept of clustering to define project areas or sub-project areas. Instead of defining a cluster to be a county, clusters may be designed to include a certain minimum number of serviceable locations within a geographic area in order to create sufficient revenue opportunities (and hence improve the business case for service providers) but, at the same time, not allow them to become too large (and thus preclude competition). The number of clusters spanning one or more counties is a parameter that will help control the cluster size. Regional ISPs can bid on clusters that they are best equipped to serve. Furthermore, nothing prevents an ISP from bidding on multiple clusters. Clusters may be constructed by combining adjacent census blocks or tracts.

Figure 1. Served, unserved and underserved locations in four-county example



To illustrate this concept, we consider an example of four adjacent North Carolina counties (Chatham, Durham, Orange and Wake) shown in Figure 1 where each shaded Hexbin (hexagonal geographic units corresponding to h3_res8 granularity from the H3 Geospatial Indexing System and spanning approximately 0.74 sq km area) contains only served locations, only unserved and/or underserved locations, or a mix of both. The four-county area is partitioned into 20 clusters where there are between 500 and 2,000 serviceable locations per cluster and there are between two and six clusters within each county (see Figure 2).

Figure 2: Clustering in four-county example. Colors in each Hexbin differentiate clusters within each county



Economic model and parameterization

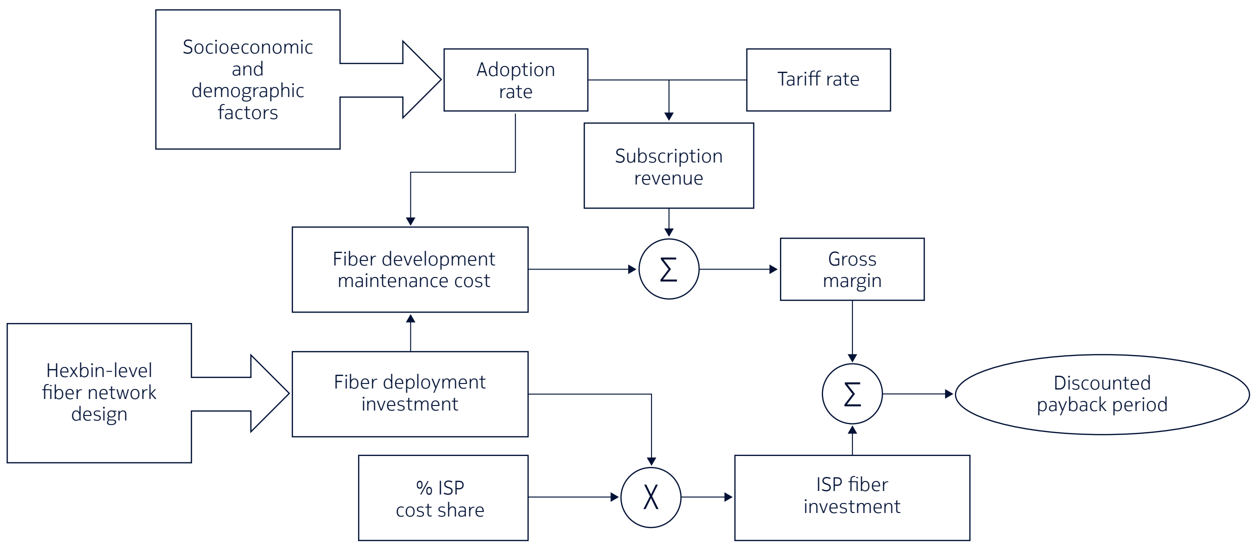
The economic sustainability of fiber broadband deployments under the BEAD program hinges on making it profitable and attractive for ISPs to invest in building and operating these broadband networks. The discounted payback period (DPP), which incorporates the time value of money, serves as a key metric that may be used by ISPs to evaluate and compare network and service infrastructure investments in different areas. ISPs typically select areas for deployment based on profitability criteria, with the DPP being a key factor to assess the economic sustainability of these investments. The DPP assesses how quickly an investment can be recouped, which is crucial for ISPs when deciding where to invest. Areas with higher densities of service endpoints, such as urban or suburban regions, generally offer a more attractive DPP because the fixed costs of infrastructure can be spread across more customers, lowering the cost per household. Conversely, rural or less densely populated areas often have a less favorable DPP due to higher costs associated with reaching fewer customers.

The initial investment per household, including costs for fiber infrastructure, optical line terminals (OLTs), and optical network terminals (ONTs) can be significant. ISPs can achieve a favorable DPP, however, with a well-designed fiber network, state-level support, and high adoption rates. This requires that revenue from subscriptions and services exceeds operational and maintenance costs, allowing ISPs to recover their investments and generate profits thus making last-mile fiber deployment a viable and sustainable venture.

Figure 3 provides an overview of ISP DPP calculations. In parallel, a predictive model for estimating adoption probabilities is developed, using socioeconomic and demographic factors to calculate adoption rates for a given area. These adoption rates in combination with a median tariff rate are then used to estimate expected subscription revenue.

In a separate analysis which feeds into DPP estimation, an optimal fiber network design is created using Hexbins to geolocate unserved and underserved endpoints. This analysis determines the total required investment for fiber deployment. Service delivery operations costs are based on connectivity to the service endpoint. The discounted payback period is then calculated through cash flow analysis.

Figure 3. Overview of ISP DPP calculations



The DPP is influenced by gross margin and investment levels. A higher gross margin reduces the payback period, while higher investment levels extend it. The investment required for fiber deployment is proportional to the number of serviceable locations and the cost of the fiber network needed to connect them. The cost of the fiber network can be represented in terms of ISP CapEx per serviceable location, which decreases as the state's cost share increases. Therefore, higher adoption rates shorten the payback period, while higher ISP CapEx per serviceable location lengthens it.

The ISP focus on profitability can result in a disparity in service availability, where more profitable areas receive better infrastructure and services, while less profitable areas, often those most in need of improved access, remain unserved or underserved. State policies such as offering cost-sharing subsidies to ISPs for buildouts or boosting adoption by providing connectivity subscription subsidies for low-income households can help mitigate these disparities by making investment in less economically attractive areas more appealing. As more households subscribe, ISPs can achieve economies of scale, lowering operational costs and increasing profitability.

The economic analysis carried out in this paper is based on the following parameters:

- Fiber deployment cost/foot
- Adoption (take) rate forecasts derived from census data [3]
- Cost to connect a new subscriber
- Yearly infrastructure OpEx/CapEx Ratio
- Yearly subscriber OpEx/CapEx Ratio
- Monthly subscriber service charge portion applied towards payback.

These parameters are set to those that have typically been observed in fiber broadband deployments in the United States. While these assumptions can vary, they are not expected to substantially impact the key insights.

In a companion paper, we have analyzed the economic sustainability of fiber broadband deployments to unserved and underserved communities [4]. We considered two deployment scenarios:

1. A greenfield scenario where unserved and undeserved locations are connected using a new fiber deployment without considering existing served locations in the same area
2. A brownfield scenario where unserved and undeserved locations are connected to existing fiber that connects served locations.

The greenfield scenario applies to new service provider entrants in an area, while the brownfield scenario applies to incumbent network expansion.

In this paper, we henceforth consider clustering with the four adjacent North Carolina counties (Chatham, Durham, Orange, and Wake) introduced earlier and consider the economic sustainability of fiber broadband networks assuming a brownfield scenario, but the observations and insights are generally applicable to brownfield scenarios, greenfield scenarios or combinations thereof.

The economics of fixed cost share

With broadband programs such as BEAD, a 25% matching contribution from Internet Service Providers (ISPs) or other non-federal sources is often targeted. This means that ISPs or other stakeholders are typically expected to contribute 25% of the project costs, with the remaining 75% funded by the BEAD program. This 25% matching requirement is intended to ensure that there is local investment in the projects, promoting sustainability and engagement from the community and private sector.

We first consider the economic sustainability for the four-county example where the counties are partitioned into a total of 20 clusters and a fixed cost share of 25% per cluster is assumed from the ISP. The fiber network is designed to interconnect all unserved and underserved locations using a brownfield approach (see Figure 4) where existing fiber is leveraged within Hexbins that comprise a mix of served and unserved/underserved locations. New fiber is introduced to interconnect Hexbins comprising only unserved and underserved locations and also to connect these serviceable locations within each Hexbin.

The brownfield design, summarized in Table 1, shows a wide variation in fiber cost per location ($3.9K - $16K) between clusters and an average cost per location of approximately $6.3K which is very similar to the case where each county is treated as a single cluster. This further validates the clustering approach since it provides more flexibility to the state in project area definition without incurring any significant cost penalty.

Figure 4: Brownfield design with clustering. Colors in each Hexbin differentiate clusters within each county.

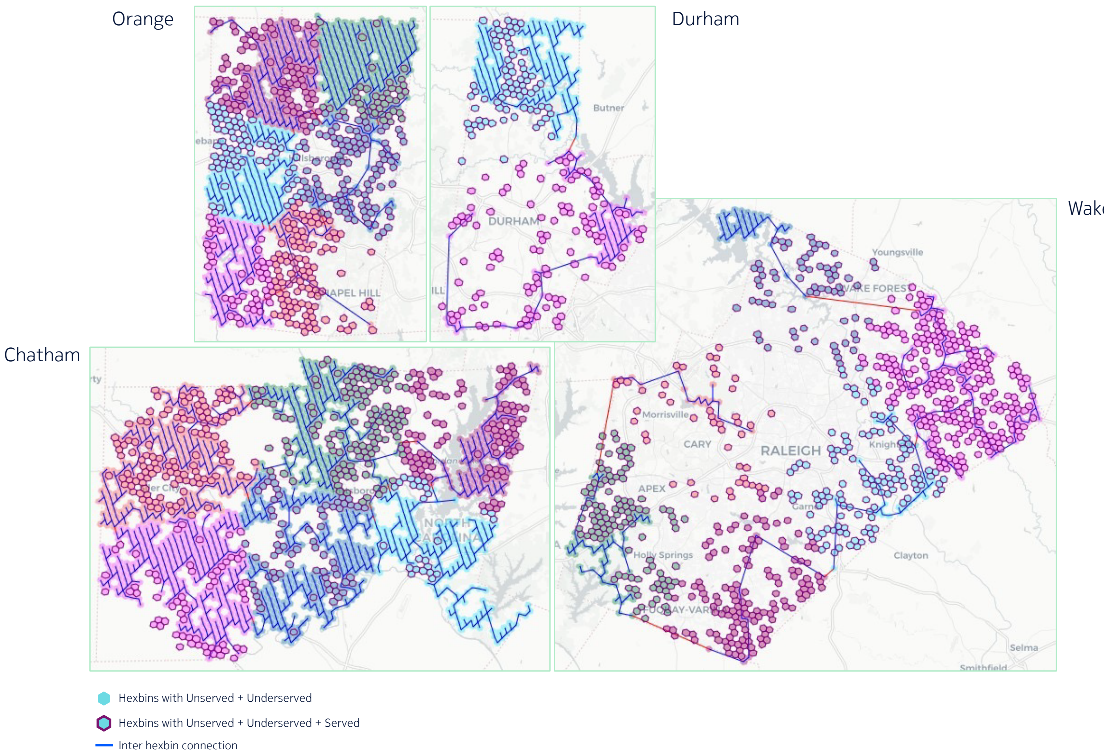
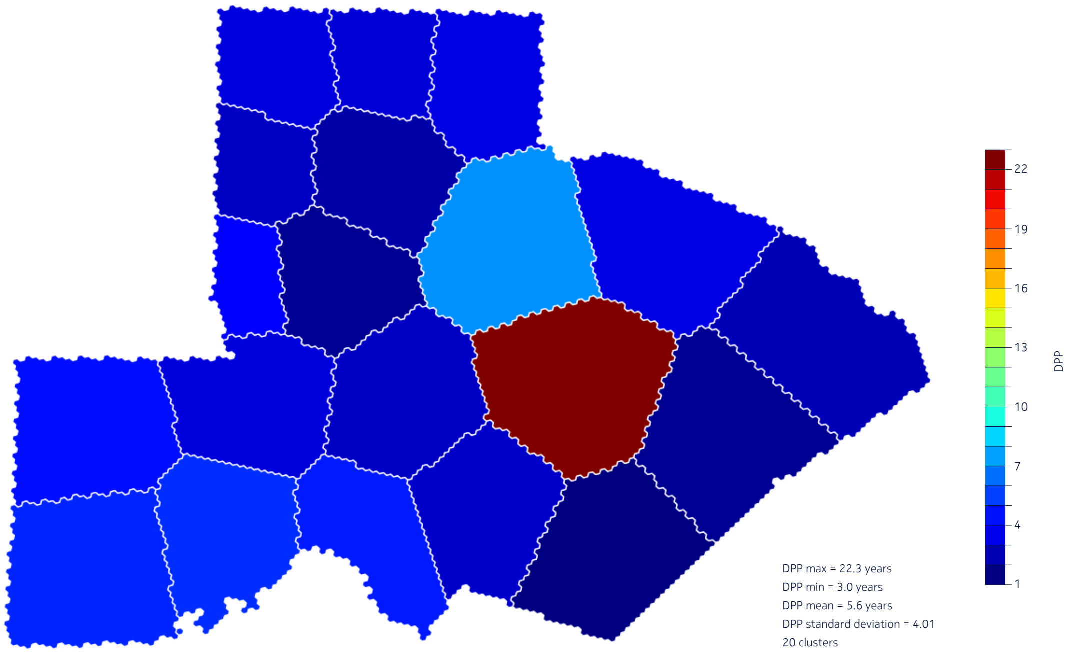


Table 1: Summary of cluster fiber lengths and cost

County	Cluster	# Locations	Fiber length (km)	Fiber cost/location ($)
Chatham	0	1,273	404	7,495
	1	2,418	696	6,803
	2	1,909	542	6,710
	3	1,952	488	5,903
	4	1,739	553	7,507
	5	1,106	260	5,553
Durham	0	1,506	398	6,247
	1	505	202	9,436
Orange	0	1,888	412	5,159
	1	938	276	6,951
	2	684	130	4,475
	3	2,026	522	6,090
	4	555	120	5,095
	5	1,445	373	6,092
Wake	0	575	107	4,392
	1	1,188	258	5,128
	2	110	75	15,997
	3	676	172	6,023
	4	477	135	6,707
	5	474	78	3,884
4-counties	**20**	**23,444**	**6,201**	**6,248**

Following the economic model described earlier, an analysis is then performed to determine the discounted payback period for the ISP to be profitable. The individual DPPs determined for all 20 clusters through this analysis are illustrated in Figure 5. The DPPs are found to be in the range of 3.0–22.3 years with an average of 5.6 years and a standard deviation of 4. The results show large variations in the DPP, making some of the clusters more attractive and some less attractive from an ISP profitability perspective. Unless some financial incentives are provided by the state government, it would be challenging to attract ISPs to deploy networks and provide service in such areas.

Figure 5. Discounted payback period with 25% fixed cost share from ISPs



Below, we address this problem by first considering a cost share optimization approach followed by an intelligent project area definition based on the grouping of clusters to achieve a level playing field among ISPs in terms of cost share and profitability.

Achieving coverage, affordability, economic sustainability, and ISP attractiveness

Variability in ISP profitability can be a significant barrier to achieving universal fiber broadband service availability across a state. It poses a challenge to BEAD's objectives, as the program aims to ensure equitable access to high-speed internet, regardless of geographic or economic factors. Addressing these disparities is crucial for fulfilling the program's mission of providing universal broadband access.

The following sections present several scenarios and mitigation strategies designed to address the issue of ISP profitability variance. These approaches, working together, may help to level the differences in ISP participation and support the broader goal of equitable service deployment.

A variable state cost share allocation approach

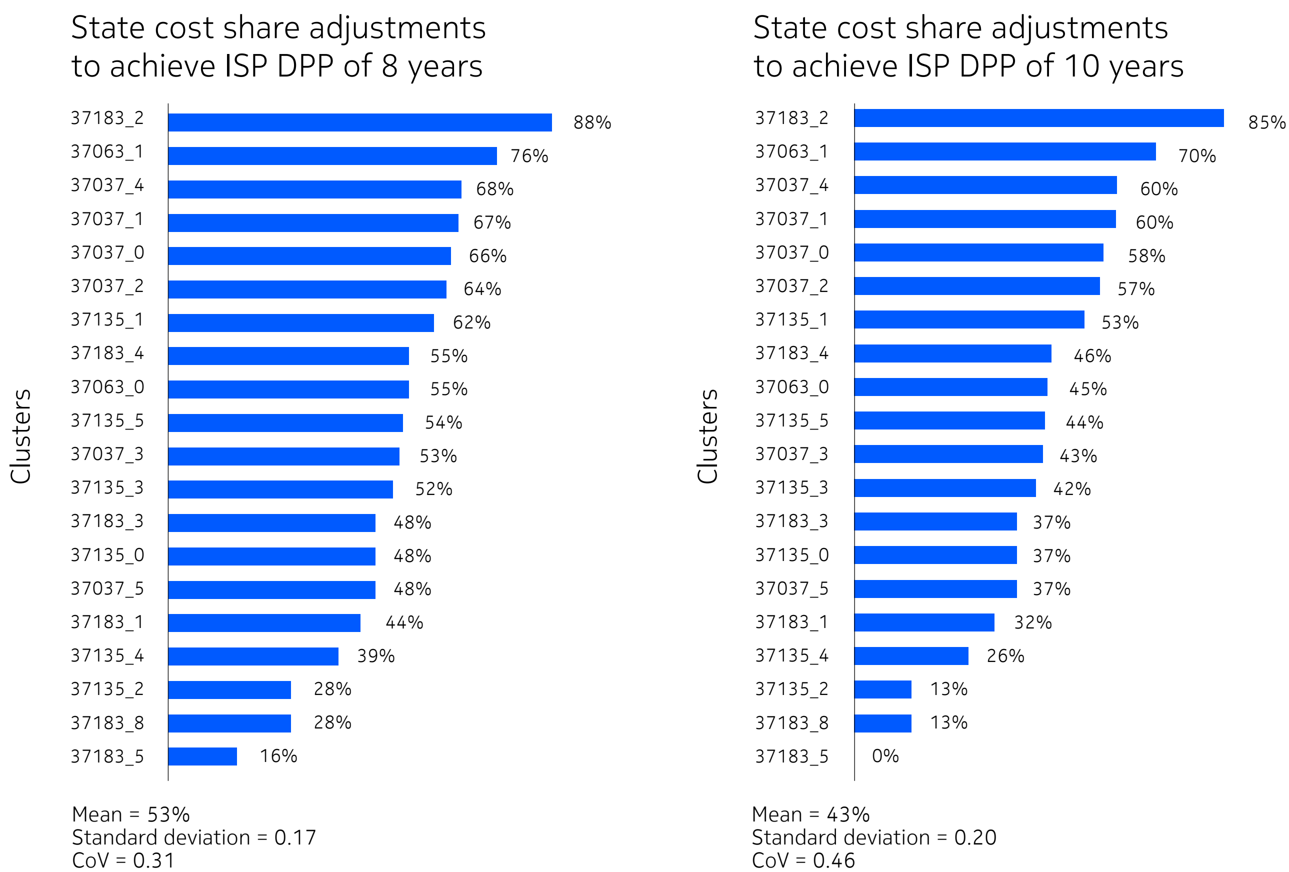
The state may address the problem of high DPPs (i.e., less attractive outcomes for ISPs) by adopting a variable cost-sharing arrangement to achieve comparable profitability for participating ISPs.

A number of factors influence the heterogeneity observed in DPP across clusters (as shown in Figure 5) including the number of households, the cost of fiber buildouts, and the expected revenue within each cluster. The coefficient of variation (CoV), defined as the ratio of standard deviation, σ, to the mean, μ, may be used to measure the extent of heterogeneity, with a lower value (e.g., ~0.1), typically indicating a higher degree of homogeneity. The CoV for DPP is observed to be 0.71, which indicates significant heterogeneity.

By adjusting its own "cost share" and implicitly the expectation from ISPs, each state can force homogeneity in profitability across clusters. Similar ISP profitability measured by DPP across clusters should increase ISP competitiveness, leading to improved consumer affordability and experience.

Figure 6 shows two scenarios where common target DPPs of eight or ten years are achieved in every cluster by adjusting the state cost share allocated to different clusters. As expected, higher target DPPs are achieved when state contributions decrease and ISP contributions increase correspondingly. Furthermore, the state and ISP cost share heterogeneity increases as evidenced by the increasing CoV.

Figure 6: Comparison of state cost share for target ISP DPPs



These points are further elaborated by Figure 7 and Figure 8. The first point is illustrated by Figure 7, i.e., a variable cost share approach with increasing ISP DPP implies a higher burden of fiber deployment cost by ISPs, although at varying cost share by geography (cluster). This has the advantage of making more funds available to the state, which it can use to cover more locations, or alternatively, to use for non-deployment programs targeting digital equity, job creation, or service enablement for remote education or healthcare.

Figure 7. Example of the average capital expenditure breakdown between the state and the ISP as a function of target DPP

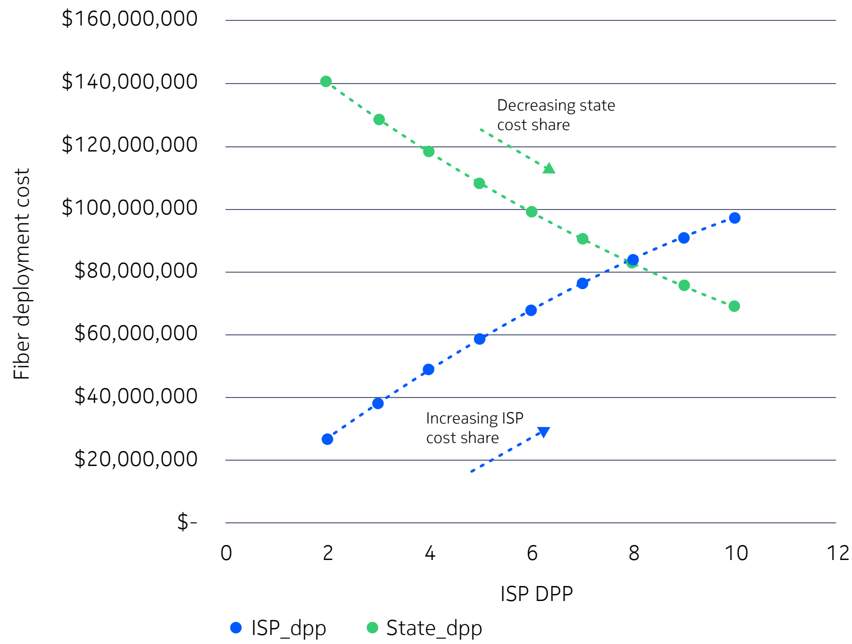
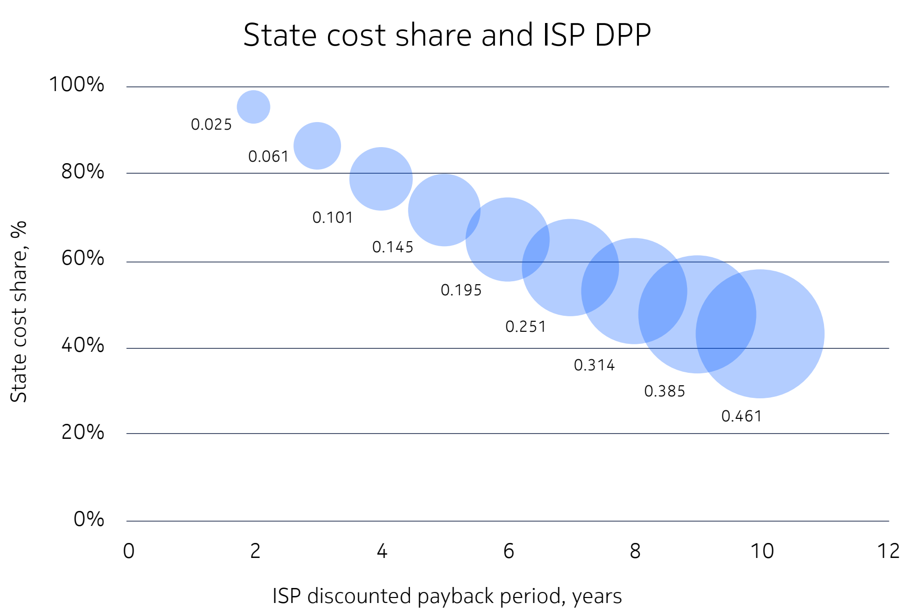


Figure 8. Coefficient of variation as a function of ISP target DPPs



Furthermore, Figure 8 indicates a widening gap in the ISP cost share per geography, as the target ISP DPP increases. A five-fold increase in target DPP (i.e., 2 to 10) results in a 17-fold increase (i.e., 0.025 to 0.461) in the CoV of the DPP. A CoV of 0.2 or lower may be a reasonable range to consider for the state in the example being considered, i.e., corresponding to a target ISP DPP of five years.

Overall, cost share optimization resulting in a variable cost share allocation per geography (cluster) may be used to enforce a similar profitability across geographies and is a relatively simple approach to remove heterogeneity concerns. That is, certain regions in the state where ISP-CapEx per household is high or adoption probabilities are low may become equally attractive if the state increases its subsidy beyond 25%. However, this increase in subsidy in certain areas must be compensated by lowering subsidy in more attractive geographies, without causing an overall increase in the state's allocated budget.

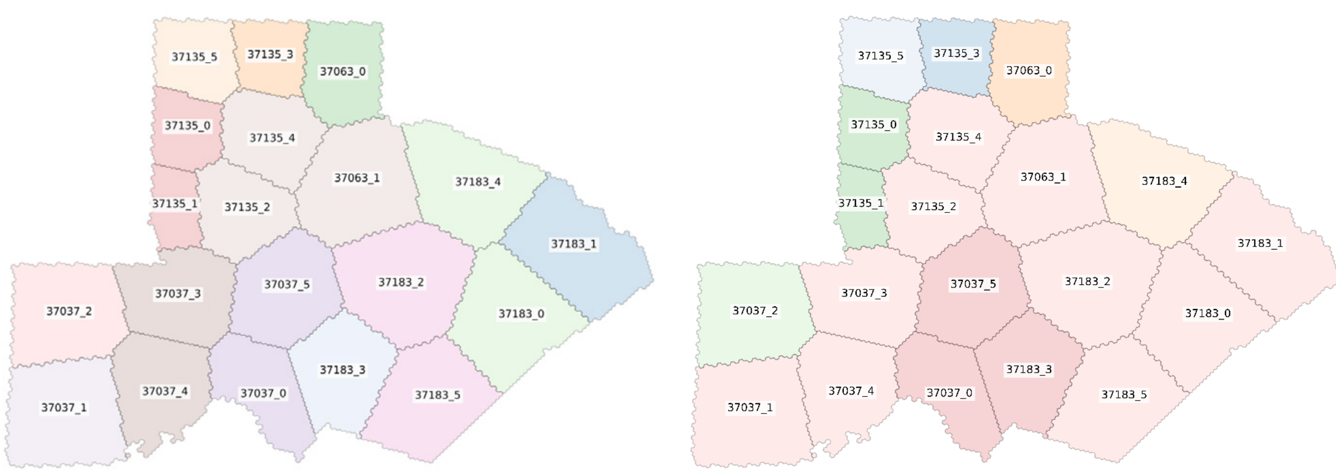
Intelligent project area designation

While cost share optimization can be carried out for any project area definition with the goal of achieving a target DPP, it can result in significant variations in terms of ISP cost share. To achieve comparable DPPs and ISP investments for participating ISPs, the state may designate project areas as newly defined groupings of contiguous clusters. Simultaneously, these groupings should minimize the CoV for both DPP and ISP investment across designated geographies to within an acceptable range.

The clusters in Figure 5 not only can vary significantly in DPP value, but in other categories such as CapEx required per cluster (see Table 2). These clusters can be combined into contiguous service areas by joining high DPP clusters with geographically adjacent low DPP clusters so as to have a more balanced DPP.

Starting with the highest DPP cluster, each adjacent neighbor is evaluated to find the lowest DPP cluster. If the DPP difference between the two clusters is above a given threshold, the clusters are merged to form a new cluster with a combined DPP value. This merging process repeats until a minimum DPP difference threshold convergence is reached. The combined clusters form service areas with more balanced DPP values as illustrated in Figure 9.

Figure 9. Clusters of similar shades indicate a contiguous project area



a)13 project areas

b) 8 project areas

Careful attention must be given to ensure that the cluster membership across project areas remains comparable in terms of total CapEx per area. Table 2 compares the initial 20 clusters with two alternative project area configurations, labeled (a) and (b) in Figure 9.

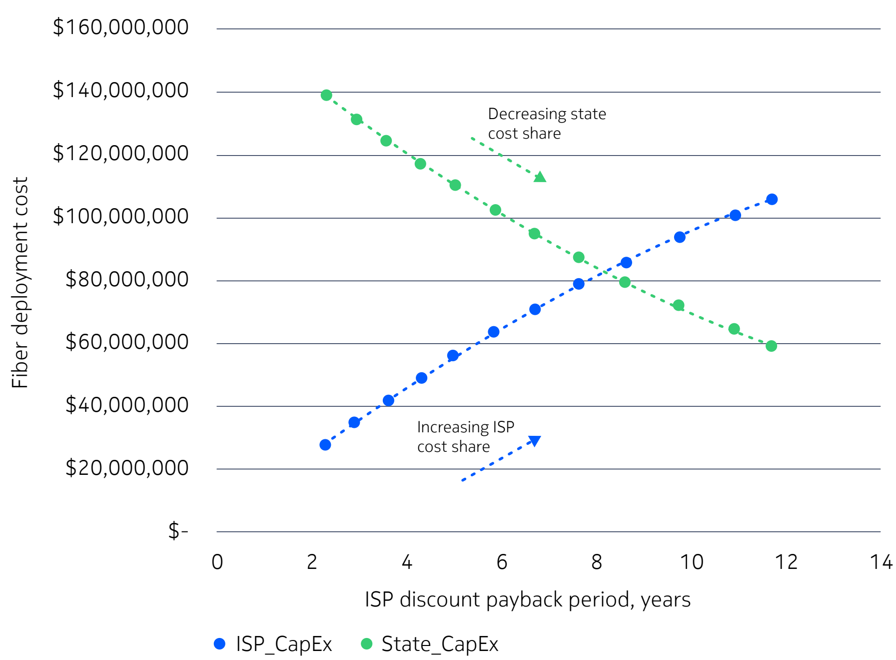
The CoVs for both these project area alternatives show superior CoVs compared to the initial 20-cluster designation. Scenario (a), with 13 project areas, shows a narrower variance in ISP CapEx but a slightly wider variance in ISP DPP. Where both Tier-1 and Tier-2 ISPs are bidding, scenario (b) may be more favorable since tier-1 ISPs may prefer covering larger areas. On the other hand, scenario (a) could be preferable in situations where smaller regional ISPs are participating, as it offers more equal opportunities for involvement.

In this approach, the state's cost share is fixed across all project areas (e.g., 25%). For decreasing state cost share, Figure 10 shows the resulting CapEx distribution between the state and participating ISPs relative to the average project area DPPs, which, while varying, remain within a narrow range. (This outcome is similar to what was observed in Figure 7).

Table 2: Project areas and variability trade-offs

	20 clusters		13 project areas		8 project areas	
	DPP (years)	ISP CapEx per location ($)	DPP (years)	ISP CapEx per location ($)	DPP (years)	ISP CapEx per location ($)
Mean	6	843,526	4.7	4,374,655	4.8	7,108,814
Standard deviation	4	1,569,283	0.6	2,118,303	0.4	6,873,700
Min	3	544,967	3.9	1,447,428	4.5	1,253,031
Max	22	5,953,753	6.2	9,281,045	5.7	24,650,625
CoV	0.71	0.55	0.13	0.48	0.07	0.97

Figure 10. Cost allocation to achieve similar ISP DPP by designating project areas



Key insights

1. Achieving universal broadband with BEAD creates new challenges for states that have not been encountered or addressed through previous programs. In particular, costs of deployment have risen and there is no longer an opportunity for “cherry picking” locations which offer an attractive business case.
2. States must make optimal use of available funds to connect all unserved and underserved communities while ensuring affordability and economic sustainability. In addition to making the appropriate broadband technology choices, this may be accomplished through optimization of cost share and project areas that are attractive to ISPs and also promote competition.
3. Rather than defining project areas based on pre-determined geographic or demographic boundaries (e.g., counties and census tracts), project areas should be defined using a clustering approach where clusters comprise a minimum number of unserved and underserved locations
4. The discounted payback period or DPP serves as a good measure of ISP profitability and economic sustainability of broadband networks.
5. Fixed cost share leads to significant variability in DPP and unacceptably long DPP for some areas, which makes them unattractive to ISPs.
6. By establishing a target DPP, the subsidy from the state (and consequently, the investment needed from ISPs) may be optimized for each cluster (or project area). A limitation of this approach is that it can lead to significant variability in the cost share required from ISPs and a perception of unfairness across ISPs.
7. Higher target DPPs result in higher variance in terms of the investment needed.
8. The variance in DPP as well as ISP investment may be reduced by optimizing project areas by combining contiguous clusters. Reducing the number of project areas advantages Tier-1 operators, while increasing the number of project areas promotes competition by facilitating participation from regional operators.
9. Greater ISP participation supports the BEAD program’s goal of maximizing connectivity to unserved and underserved locations. To achieve uniform profitability for ISPs, as measured by the DPP, the state should leverage cost-sharing arrangements and designate specific geographies where ISPs can compete effectively.

Abbreviations

ARPA	American Rescue Plan Act
BEAD	Broadband Equity, Access and Deployment program
BIP	Broadband Infrastructure Program
CAF	Connect America Fund
CapEx	Capital expenditures
CoV	Coefficient of variation
CPF	Capital Projects Fund
DPP	Discounted payback period
EHCT	Extremely high cost per location threshold
FTTx	Fiber to the home, curb, antenna, building, premises, node, etc.
FWA	Fixed wireless access
Hexbin	Hexagonal binned plot
ISP	Internet service provider
NTIA	National Telecommunications and Information Administration
OLT	Optical line terminal
ONT	Optical network terminal
RDoF	Rural Digital Opportunities Fund

References

[1] Balachandran, K., et al., "Going the Extra Mile with BEAD Intelligence: Assessing the Incumbent Advantage," Bell Labs Consulting, Aug 2024. URL:

[2] Emergency Petition filed before the FCC, Coalition of RDoF Winners, August 2023.

[3] US Census Bureau, 2024. URL: https://data.census.gov/table

[4] Broadband Serviceable Location Fabric, Federal Communications Commission, May 14, 2024 version.

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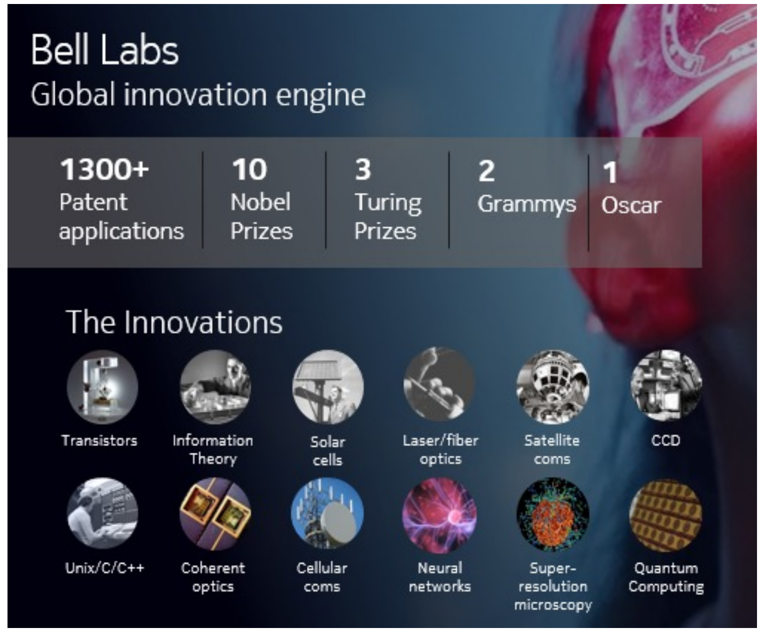

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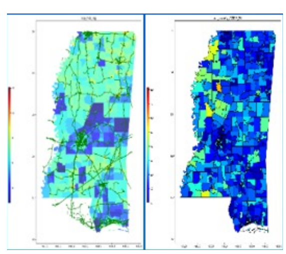
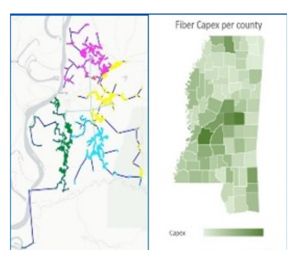
Cost-efficient, intelligent broadband network design and economic analysis to meet each state's unserved and underserved community needs

Data-science driven insights that help determine intelligent project area definitions, broadband technology choices and sustainable investment strategoes to extract the greatest socio-economic value.

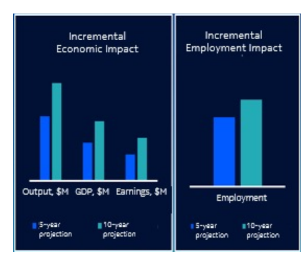
Bell Labs Consulting brings outstanding innovations and in-depth techno-economic modelling expertise for driving cost-efficient universal broadband adoption across the nation.



Data modelling and classification



Optimal fiber network design and prioritized zones of investment



Stimulating industry-driven socio-economic growth

About Nokia

At Nokia, we create technology that helps the world act together.

As a B2B technology innovation leader, we are pioneering networks that sense, think and act by leveraging our work across mobile, fixed and cloud networks. In addition, we create value with intellectual property and long-term research, led by the award-winning Nokia Bell Labs.

With truly open architectures that seamlessly integrate into any ecosystem, our high-performance networks create new opportunities for monetization and scale. Service providers, enterprises and partners worldwide trust Nokia to deliver secure, reliable and sustainable networks today – and work with us to create the digital services and applications of the future.

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