Final Project Writeup

Mobile Data Access: Understanding Context for Globally Inclusive UX

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Links: website, video demo, full-length screenshot

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1. Project goals

Our project aims to evoke empathy for mobile internet users experiencing high-cost and slow-speed mobile internet among digital product strategists and designers primarily in the United States. The narrative and visualizations on our website are intended help our audience compare the affordability and speed of mobile internet in the United States to those in four of the largest, growing markets globally which represent a range of regions and income groups (i.e. Brazil, Ethiopia, India, Nigeria).

We chose to anchor our comparisons relative to the United States because it is a hub for technology development and mobile internet inclusivity is particularly vulnerable to being overlooked in Silicon Valley for several reasons. Firstly, mobile data contracts and the prevalence of wireless internet result in users rarely carefully managing the cost of their data consumption in the US context. Secondly, connectivity tends to be strong in the United States, especially in the contexts in which technologists live and work.

By visualizing cost and speed comparisons between the United States and the four other countries, we encourage our Silicon-Valley-based audience to adopt a more inclusive perspective and understand how mobile-internet-heavy products may result in poor user experiences globally.

Our visualizations work to accomplish the following low-level tasks:

- **Present an introduction** to two often overlooked aspects of mobile internet inclusivity (affordability and speed).
- **Compare the affordability** (as defined by the Alliance for Affordable Internet) **and speed** of mobile internet between the United States and countries abroad through the perspective of users' experience. For the scope of this project we compared the United States to four other countries that cover different regions, different income groups, almost 30% of the world's population, and growing markets for mobile internet use.
- **Assist product strategists and designers in identifying extrema** among countries where internet accessibility and speed is particularly challenging and as a result should be given special consideration when launching in or designing for such countries.

2. Related work

This project drew from global development oriented research on technology for development and was inspired by publications and resources oriented toward building more inclusive products. The former provided the data and background for speed and affordability as challenges of mobile internet access. The latter provided the approach for orienting these challenges toward building a more inclusive user experience and also highlighted a lack of

attention on these particular issues in inclusive product design and development.

2.1 Mobile Internet Related Work

Alliance for Affordable Internet. "Mobile Broadband Pricing". Retrieved from: https://a4ai.org/research/mobile-broadband-pricing/.

The Alliance for Affordable Internet (A4AI) is a research and advocacy coalition hosted by the World Wide Web Foundation. As part of their research, they collaborate with the International Telecommunication Union (ITU) and draw from the World Bank's income data to produce an annual, most recently 2021, dataset on the absolute pricing of mobile internet and the affordability of mobile internet (absolute pricing as it relates to local income) globally. This dataset informed our affordability data visualizations and A4AI's positioning of this data within their larger work on making the internet more accessible reinforced the importance of affordability as a user constraint. While A4AI provides some visualization of their mobile broadband affordability research, the visualizations are limited and, as their work is oriented toward policy, not contextualized in user experience. (See Fig. 1) The visualization is oriented instead toward understanding global trends and providing access to the data for a variety of use cases.

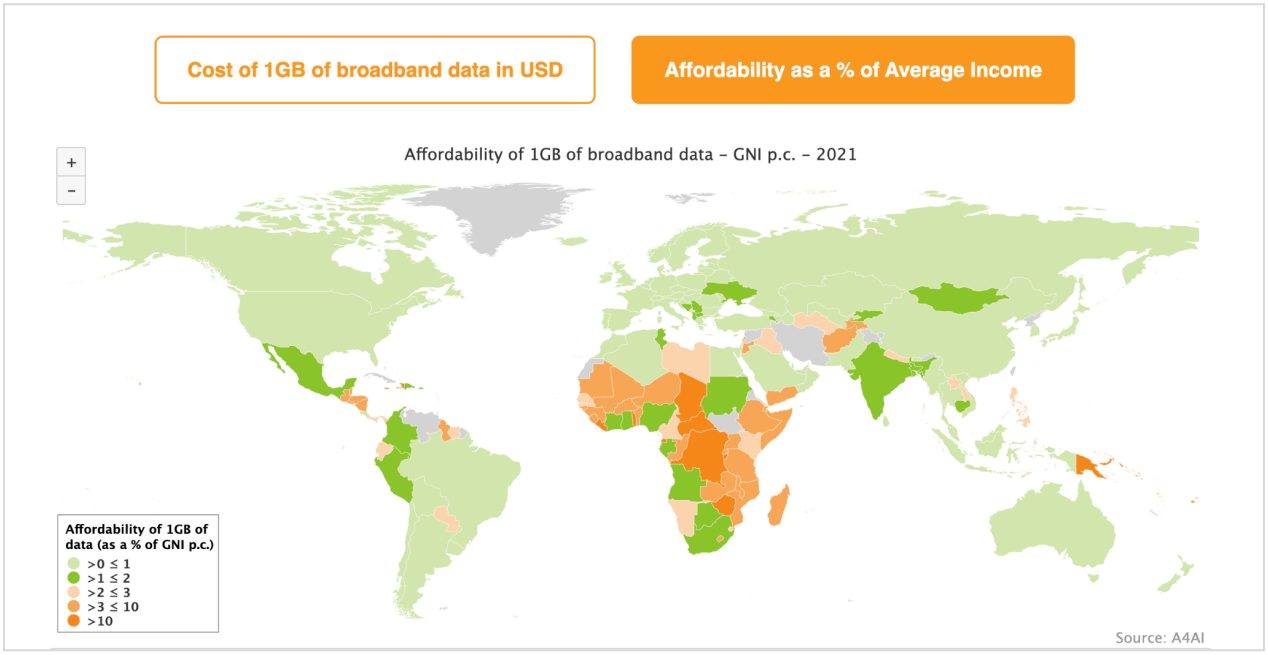
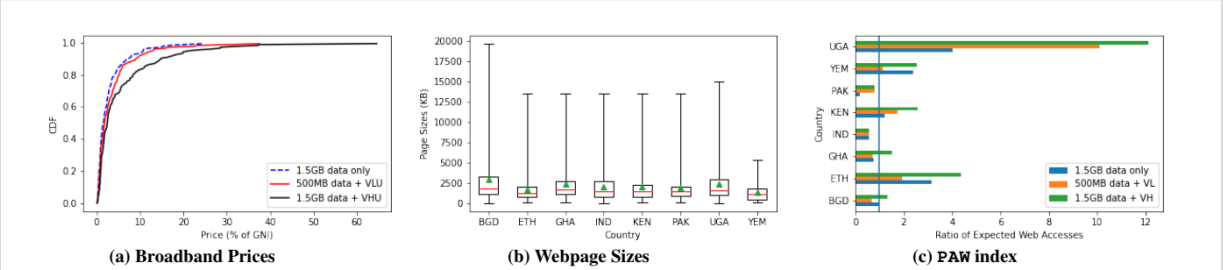


Figure 1. A4AI's interactive visualization of mobile broadband affordability. Link.

Ihsan Ayyub Qazi, Zafar Ayyub Qazi, Ayesha Ali, Muhammad Abdullah, and Rumaisa Habib. 2021. "Rethinking Web for Affordability and Inclusion". *In Proceedings of the Twentieth ACM Workshop on Hot Topics in Networks (HotNets '21)*. Association for Computing Machinery, New York, NY, USA, 9–15. https://doi.org/10.1145/3484266.3487376

This paper proposes a new framework for building more affordable and inclusive products by measuring data and developing leaner web architecture for contexts in which access is expensive. In defining the problem space, they describe how the ongoing high cost and increasing complexity of the web are a barrier to affordable access in many regions. This research contributed to the case we make on the website that while affordability and speeds have improved, increasing web complexity continues to drive a wider divide for those with less access. In the solutions they describe, they validate that factoring these barriers into Web architecture is both feasible and critical for inclusivity. Although this paper included helpful visualizations pertaining to affordability and webpage sizes, we ultimately explored alternatives to line graphs and boxplots in our own project. (See Fig. 2)



(a) Broadband Prices **(b) Webpage Sizes** **(c) PAW index**

Figure 1: (a) Mobile broadband prices as a percentage of GNI per capita across 176 countries for three plans. 42%–55% of the countries do not meet the affordability target of 2% across the plans, (b) distribution of landing webpage sizes for Alexa top 100 websites from 8 developing countries: Bangladesh (BGD), Ethiopia (ETH), Ghana (GHA), India (IND), Kenya (KEN), Pakistan (PAK), Uganda (UGA), and Yemen (YEM). Green triangles represent the average sizes and (c) ratio of mean Web accesses across 8 countries relative to the affordability target and the mean global page size of 2.39 MB based on Alexa top 100 websites globally. The vertical line at x=1 shows the ratio at the global benchmark level and bars exceeding 1 do not meet the target.

Figure 2. Qazi et. al.'s visualizations of affordability and size considerations across countries

ITU. *Global Connectivity Report 2022*. Retrieved from: https://www.itu.int/itu-d/reports/statistics/global-connectivity-report-2022/.

Prepared by the International Telecommunication Union, the UN agency dedicated to information and communication technologies, this report is likely the most updated and thorough evaluation of the state of global internet access. The report reinforces the importance of affordability and speed in the digital divide and provides other context for our analysis, including that prepaid plans remain the standard in low and middle income countries, for example. As shown in Fig.3., their visualizations focus on region and income group trends and given the variation within the groups, we wanted to provide more insight into specific country dynamics.

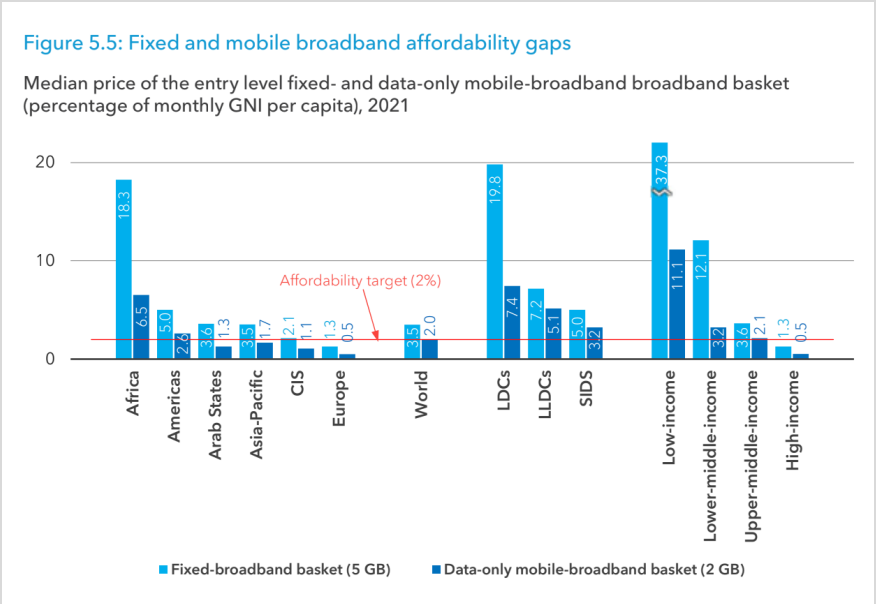


Figure 3. ITU's visualization of affordability by region and income group

Mathur, A., Schlotfeldt, B., & Chetty, M. (2015-09-07). A mixed-methods study of mobile users' data usage practices in South Africa. *Paper presented at the 2015 ACM International Joint Conference*, 1209-1220. doi:10.1145/2750858.2804292

Related: **Chetty et al. (2011). "While the Meter is Running: Computing in a Capped World". *Interactions*.**

While this paper may be considered outdated given the pace of technology, because other data indicates that affordability continues to be a constraint and prepaid (pay-as-you-go) or data-limited phone plans are the standard in many countries, its findings remain relevant. The paper explains ways in which mobile phone users cope with prepaid or data-limited plans—primarily that they consciously manage how they are consuming data to maximize the limited supply. This study supports the framing in our project that the amount of data an application requires is a key element of users' experience in contexts where data is expensive. The quote below highlights the user impact of high data usage:

> "Participants also learned about what consumed data from running out of data fairly quickly because of engaging in a certain activity such as watching a video and coupling this with checking their data balances. Based on this knowledge, they often closed these applications and killed processes in an attempt to reduce data usage. For example, P12 reported: "To cut costs on mobile data, I normally just turn off applications on my phone that require a data connection." (p. 1216).

United Nations Broadband Commission. "Advocacy Targets". Retrieved from: https://www.broadbandcommission.org/advocacy-targets/2-affordability/.

The Broadband Commission is a UN advocacy organization formed through a public private partnership. In 2018, they set the target for affordability of the web that continues to be the goal today. This affordability target was an important reference point for the framing of the affordability data in our project—the fact that many countries haven't met it is a clear indication of the ongoing constraint of affordable internet. This site also highlights that the affordability target currently set at 2% of income for 2GB per month is a limited estimate and does not provide for more data intensive applications of today. They cite that while 660MB per user per month may be sufficient for internet-based public service access, 6GB is a more realistic assessment if recreational apps, such as social media, are used. This analysis supported our framing of data usage across popular apps.

2.2 Inclusive UX Related Work

- **Adobe Spectrum. "Inclusive Design." Retrieved from https://spectrum.adobe.com/page/inclusive-design/.**
- **Google Belonging. "Inclusion and Accessibility." Retrieved from: https://about.google/belonging/disability-inclusion/product-accessibility/.**
- **Microsoft Inclusive Design. Retrieved from: https://inclusive.microsoft.design/.**
- **Wikimedia Foundation. "Wikimedia Foundation's Inclusive Product Development Playbook". Retrieved from: https://www.mediawiki.org/wiki/Wikimedia_Product/Inclusive_Product_Development/Draft_Playbook**

The practice of inclusive design in digital product development has evolved rapidly in recent years. The inclusive design resources above demonstrate that leading technology companies are investing in and promoting inclusive design. Inclusive design grew out of accessibility and accessibility in product development has historically focused on accessibility for differently abled users (see W3 Accessibility Fundamentals), and so designing for diverse abilities has continued to dominate the inclusive design discourse. Some resources also provide guidance for design inclusive of different identity groups—races, genders, social orientation, etc. The ethos of the work—centering diverse users—lends itself to inclusivity of all possible identities and contexts. However, the design exercises, checklists, and case studies embedded in these resources rarely address some of the key challenges of globally accessible technology—from multilingualism to mobile internet affordability and speed. While affordability and speed may be more of a focus at the development phase, and so oriented toward engineering resources rather than design, understanding users' needs and strategic choices about the types of features built start early—discovery and ideation. This gap in the resources inspired the focus for this project, and the approach we adopted to trying to put our viewers in the shoes of users with mobile internet constraints was inspired by the emphasis of empathizing with users set in these resources.

Google Next Billion Users. "Designing for Global Accessibility." Retrieved from https://nextbillionusers.google/tools/designing-for-global-accessibility/.

Google's Next Billion Users project "Designing for Global Accessibility" series serves as a rare resource addressing globally inclusive design. The series starts where this project focuses: "Awareness is everything". In order for digital product strategists and designers to build for diverse users, they have to understand diverse contexts. This resource provides prompts for consideration but is brief. This project seeks to add color and data to help viewers engage and internalize the challenges of mobile internet access.

3. Visualization

We structured our narrative into five themed sections, starting with (section 1) a broad introduction about the importance of affordability and speed on a global level, followed by (section 2) a closer look at the state of mobile internet in five specific countries, then diving deeper into the (section 3) affordability and (section 4) speed in these five countries, and closing with (section 5) considerations that digital product strategists and designers should keep in mind when building for globally inclusive user experiences. Overall, we styled our website to have wide margins, making the text blocks narrower and quicker to scan than text blocks that span the entire width of the page. Inspired by publications like The New York Times that specialize in visualizations, the narrow alignment and ample white space between blocks aims to make the information less overwhelming and help viewers focus on the text or chart that predominates their screen, one at a time.

3.1 Section 1: Introduction and Global Overview

To entice our target audience (digital product strategists and designers primarily in the United States) and give them a preview of the website's purpose, this section aims to emphasize the importance of affordability and speed on user experience; mainly, affordability limits access and speed limits satisfaction.

We used a scatterplot to show that many countries do not meet the target for mobile internet affordability (UN Broadband Commission, ITU Affordability of ICT Services) and so managing the cost of using a product is an ongoing calculation for users in low- and middle-income countries. (See Fig. 4) This chart highlights in blue the points above the UN Affordability Target line to draw attention to the countries where mobile internet affordability is an issue. And for audiences who are curious, we designed a tooltip interaction on this, and the following, scatterplot that reveals the country each dot represents.

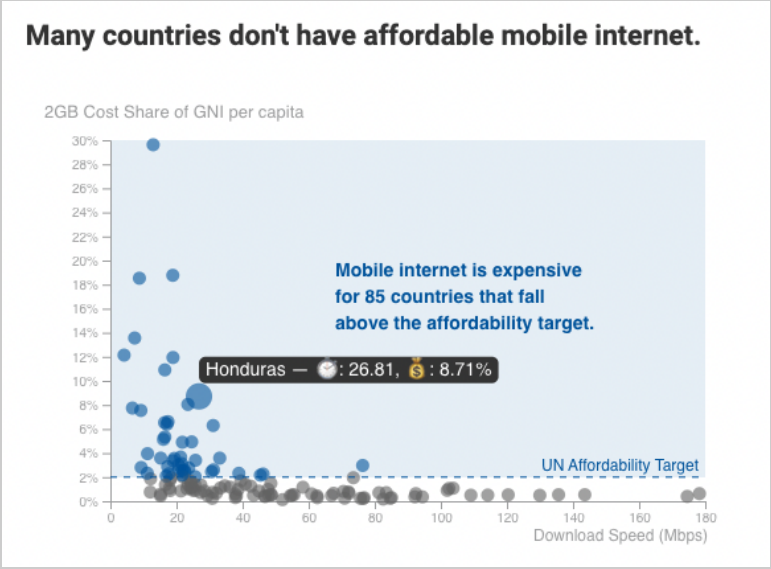


Figure 4. Scatterplot highlighting countries where internet affordability is an issue. A tooltip interaction reveals the country, its download speed, and 2GB cost share of GNI per capita.

A second scatterplot shows that many countries also fall below the average mobile internet speed. (See Fig. 5) We use this visualization to convey the idea that although the average mobile internet speed increased by 60% over the last five years (Ookla Global Speed Test), it falls short of the median mobile web page transfer size which increased by 57% over the same period (HTTP Archive). Similar to the first, this scatterplot highlights in orange the countries where internet speeds are less than the global average to emphasize the prevalence of this challenge.

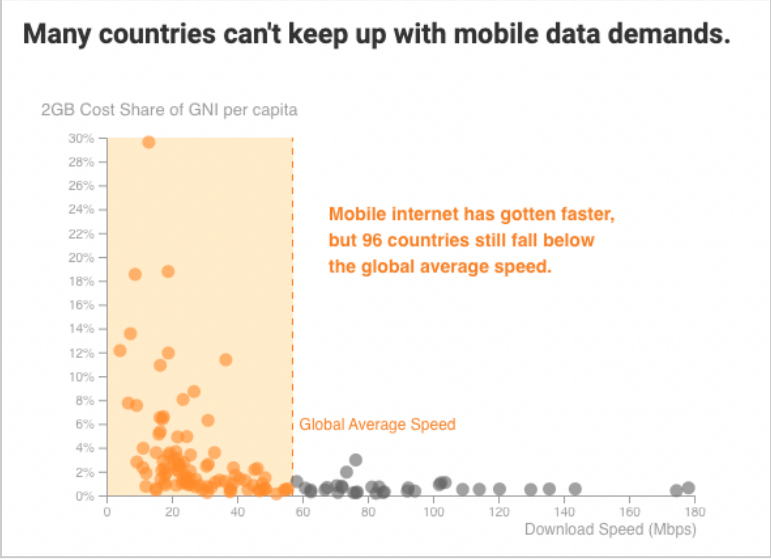


Figure 5. Scatterplot highlighting countries where slow internet speeds are an issue. A text annotation is included to summarize the main insight for audiences.

While we wanted to provide interested viewers with access to global data, we aimed to simplify the intended takeaway of this scatterplot visualization through repeating it twice—once for affordability and once for speed—and using color, enclosure, and annotation to visually prioritize the key information. Overall, this introductory section is intended to give our audience a high-level view of the range of mobile internet costs and speeds around the world before diving into a few select countries in the next section.

3.2 Section 2: Country Focus

This section introduces our audience to the five countries that will be the focus in the sections to follow and the rationale behind this selection. (See Fig. 6) Because affordability and speed of mobile internet varies widely across regions and income groups, we wanted to highlight for our audience a diverse sampling of five countries: The United States, Brazil, India, Nigeria, and Ethiopia. Not only is this selection a diverse sampling, but these countries also represent almost 30% of the world's population and growing markets for mobile internet use, suggesting that our audience may have a strong business case to take special interest in these markets.

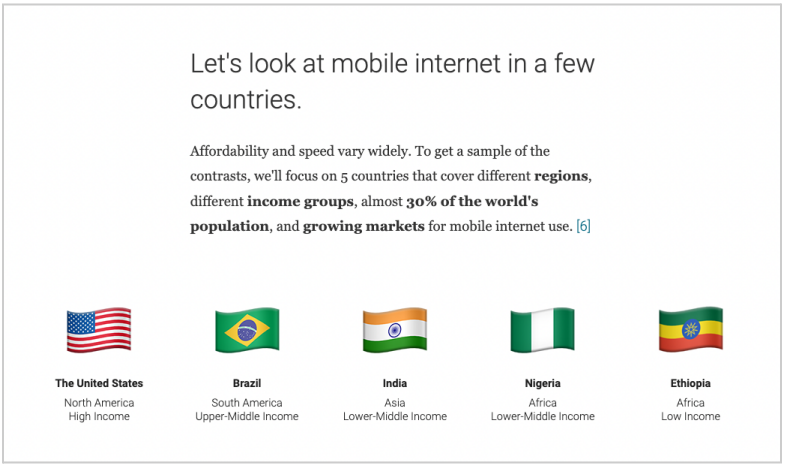


Figure 6. A lineup of the five countries selected for further comparison in the sections to follow. Easily recognizable flag icons are used to represent each country.

To visualize the diversity within this group of countries, this section includes an interactive radar-chart activity where viewers are invited to guess the country based on its Mobile Connectivity Index scores for mobile ownership, affordability, 4G coverage, and mobile download speed. (See Fig. 7) Inspired by the New York Times's You Draw It format, we designed this interactive visualization to engage our audience and prompt them to reflect on their familiarity–or unfamiliarity–with the mobile internet conditions in these five countries. After placing their guesses via the dropdown menu, our audience can click a button to reveal the correct countries associated with each radar chart. We intend for this activity to be more of an engaging learning moment and less like a quiz where our audience feels pressured to already know the correct answer.

Figure 7. Small-multiple radar chart activity where the audience is asked to guess the country using the dropdown menu. A button at the bottom reveals the correct answers.

3.3 Section 3: Affordability

Now that our target audience has been acquainted with our five selected countries, we challenge them to consider the cost of mobile internet in each country relative to the local incomes. To conceptualize affordability as "cost share", we borrowed and illustrated Alliance for Affordable Internet 2021 Mobile Broadband Affordability's definition: the percent cost of 1 GB of mobile internet out of a person's average monthly income in that country—adjusted to daily income to more easily contextualize with app usage amounts. (See Fig. 8)

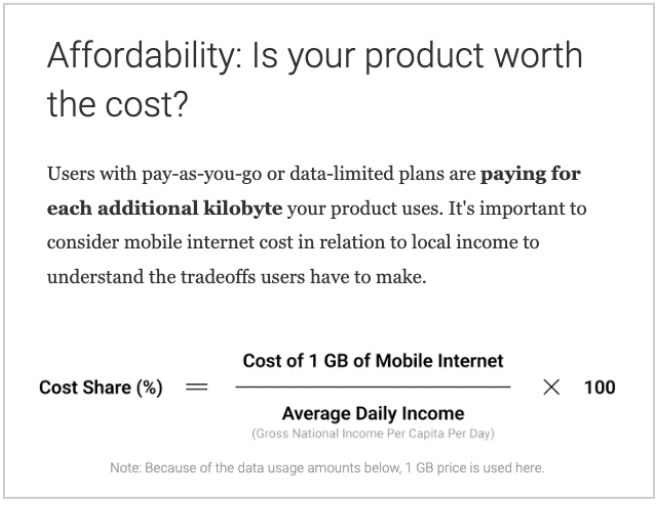


Figure 8. Equation to explain the definition of affordability as "cost share".

To continue engaging our target audience, we created a set of interactive bar charts showing how many hours people could use popular apps (Instagram, Netflix, and Google Maps) before consuming their entire average daily income, represented as a dotted reference line at the 100% tick mark on each bar chart. (See Fig. 9) The interactive slider control allows our audience to explore and scale the cost (as percent of daily income) of each app in each country, except the United States; because mobile internet per GB pricing is rarer in the United States, we excluded United States data in this visualization and noted this exception in a footnote on our website.

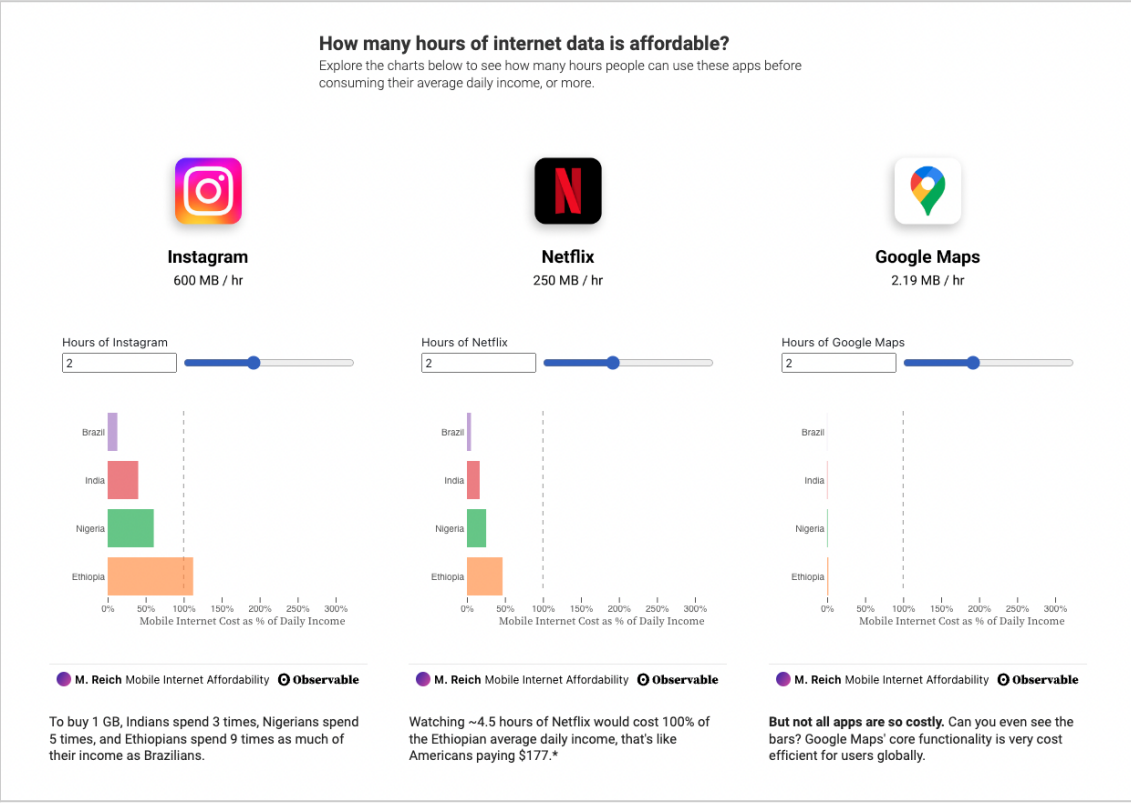


Figure 9. Small-multiple, interactive bar charts showing the cost of using each app in each country as a percent of daily income. Slider functionality allows the user to scale the chart by a quantity of hours in quarter increments.

Additionally, this interactive functionality enables our audience to put the cost of their own app usage habits into perspective by using the slider to specify how many hours they personally spend on each app. We designed this visualization to encourage our audience to think about how affordability is influenced both by local income and also the amount of mobile internet data required to use an app. For example, “watching ~4.5 hours of Netflix would cost 100% of the Ethiopian average daily income, that's like Americans paying $177” and the very short (almost non-visible) bars on the Google Maps chart show that its functionality is very cost efficient and therefore more affordable for users globally.

We chose to spotlight Instagram, Netflix, and Google Maps for their variety in function (i.e. social media, entertainment, navigation) and for their range of data demands; Instagram consumes the most data at 600MB/hr and Google Maps consumes far less at 2.19 MB/hr. Although these three apps may not be the most popular in our selected countries, they are widely used in the United States, putting data usage considerations in perspective of apps with which they are likely familiar.

3.4 Section 4: Speed

To convey the impact of speed–or lack thereof–on the user's experience, we attempted to simulate the frustration a user feels when waiting for long load times by animating a set of cards to "load" with a spinning progress wheel for a given amount of time ranging from 100 milliseconds to 10 seconds. (See Fig. 10) After the play button is pressed, each card describes the effect of the given time delay on the user's experience and corresponds to a colored section on the timeline. We created this timeline to give temporal context to and visualize the order of the progressively detrimental load-time effects. This visualization was partially inspired by this interactive visualization of NYC street trees and informed by Deloitte Digital's research on the UX cost of slow speeds.

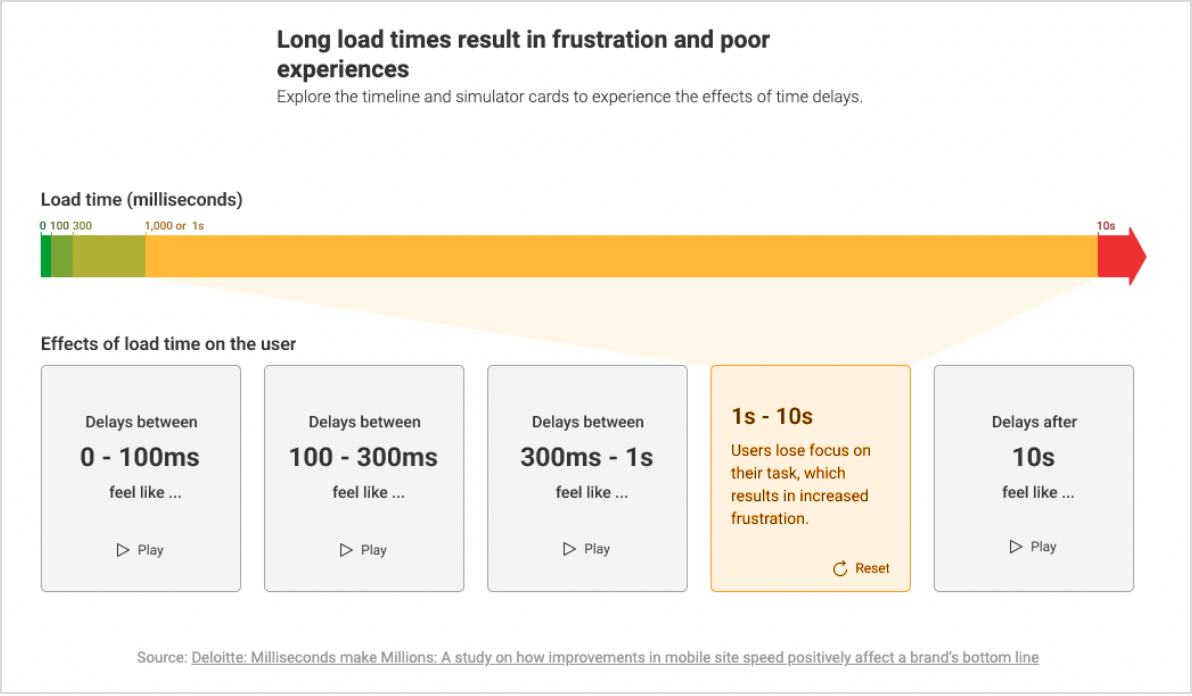


Figure 10. Cards with timeline used to simulate the frustration people feel while waiting for data to load. Hovering over a range on the timeline highlights the corresponding card for that time range. The red "10 second" time range is truncated due to space constraints, but the widths of the other time ranges are scaled proportionally.

Similar to the previous section about affordability, this section aims to put mobile download times into perspective by using an animated bar chart to visualize how long it takes to download approximately 18 songs on Spotify in each of our five selected countries. (See Fig. 11) The bar for each country animates–or "loads"–into the graph according to the download speed (in seconds), and so this animation simulates the frustrating effects of long load times. For example, our audience must wait longer than 22 seconds for the Ethiopia bar to fully "load". We chose to visualize Spotify data because audio files are a practical file type to download (i.e. for offline access). Initially, we considered visualizing Instagram, Netflix, or Google Maps data to be consistent with Section 4. However, users typically do not "download" discrete amounts of data from these apps, rather they scroll an infinite feed on Instagram, stream content on Netflix, and use Google Maps for variable times depending on trip length. To make this visualization more clear and relatable for our audience, we chose to visualize a discrete quantity of data (45 MB) which is approximately 18 songs.

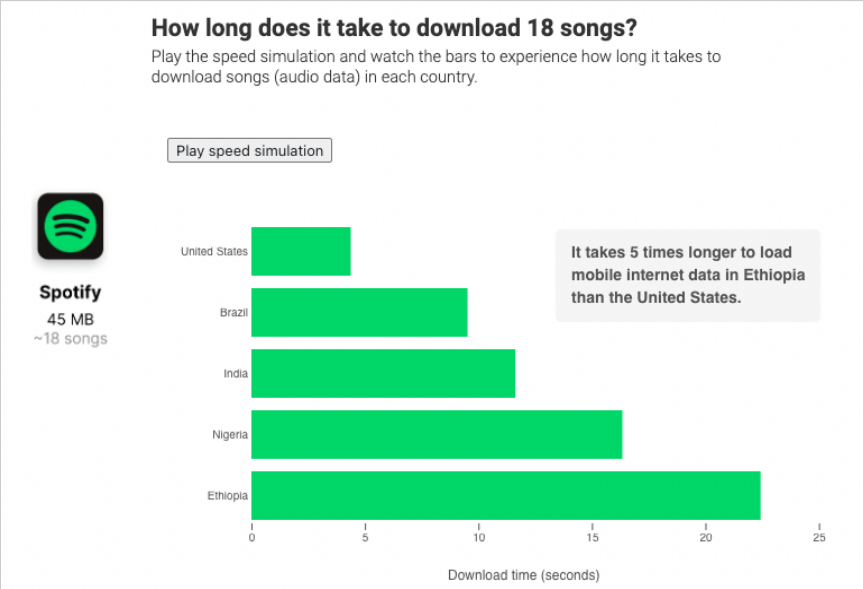


Figure 11. Animated bar chart showing how long it takes to download 18 songs on Spotify, a popular app in the United States. A "play" button allows the user to replay the animation.

3.5 Section 5: Things for our audience to keep in mind

Lastly, our website provides our audience with a list of specific questions, reminding them to consider the affordability and speed of their mobile products and how they impact their users around the world. (See Fig. 12) This call to action is specifically geared towards our target audience of digital product strategists and designers working primarily in the United States. In addition to bulleted lists being a UX writing best practice according to Nielsen Norman Group, this list format is inspired by the writing styles in popular publications (e.g. Business Insider, WhistleOut, Medium) that our target audience may be familiar with.

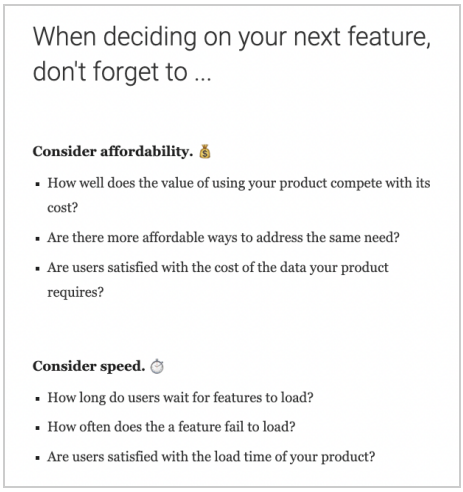


Figure 12. List of questions to help our target audience think about how mobile internet affordability and speed may affect their users.

4. Data

4.1 Mobile Internet Affordability

- **Alliance for Affordable Internet. "Mobile Broadband Pricing". Retrieved from:** https://a4ai.org/research/mobile-broadband-pricing/**.** As described in the related work, A4AI's mobile broadband pricing and affordability data set was a core resource for our affordability analysis, particularly the 2021 data on 1GB and 2GB mobile broadband cost as share of Gross National Income (GNI) per capita. A4AI partners with the UN ITU to produce this dataset, and so it seems to be the most comprehensive pricing data available.
- **United Nations Broadband Commission. "Advocacy Targets". Retrieved from:** https://www.broadbandcommission.org/advocacy-targets/2-affordability/**.** As described above, in addition to context for our framing, this site provided one specific data point highlighted as a line in our affordability charts—the UN mobile broadband affordability target of 2% of GNI per capita for 2GB.

4.2 Mobile Internet Speed

- **Ookla. *Speedtest Global Index*. Retrieved from:** https://www.speedtest.net/global-index. This seems to be the most comprehensive publicly available data on strength of connectivity available, validated by the GSMA and ITU's reference to it. The mobile download data was a core resource for our visualizations on speed.
- **Deloitte Digital. *Milliseconds Make Millions*. Retrieved from:** https://www2.deloitte.com/content/dam/Deloitte/ie/Documents/Consulting/Milliseconds_Make_Millions_report.pdf. This report provided data for the speed simulation to

contextualize how significant even small differences in download speed are for the user experience and product success.

- **HTTP Archive. *State of the Web*. Retrieved from: https://httparchive.org/reports/state-of-the-web. This report provided data on the increasing complexity of the web which was an important data point for describing why improved internet speeds have not closed the digital divide in speed.**

4.3 Country Mobile Internet Landscape

- **GSMA. "Mobile Connectivity Index Indicator Scores". Retrieved from: https://www.mobileconnectivityindex.com/connectivityIndex.html#year=2021&dataSet=indicator. The GSMA is a non-profit industry membership organization of mobile network operators that produces some of the most comprehensive data on mobile access. The Connectivity Index is an annual report which ranks countries' mobile connectivity, from infrastructure to skills to make use of the value it offers. The composite score is based on a number of indicators of diverse elements of connectivity on which countries are scored from 1 to 100. We used four of these indicators closely aligned with mobile internet access in our radar charts to give users a higher level sense of the context of the countries on which we focused.**

4.4 Mobile App Data Usage

As noted on our website, the exact data mobile apps consume varies depending on the specific activities and context of use, and the amounts we used for reference are approximations. We used a combination of these sites to set a conservative estimate for our analysis. While other more raw data on affordability and speed is available in our project, we thought it was critical to put that data into perspective of product experiences our viewers could relate to and perhaps relate the applications on which they work, even if approximate.

- Casserly, Martyn. (July 2022). "How much data does Instagram use?". *TechAdvisor*. Retrieved from: https://www.techadvisor.com/article/812725/how-much-data-does-instagram-use.html.
- Clark, Stephen. (November 2020). "How Much Data Does Spotify Use?". *WhistleOut*. Retrieved from: https://www.whistleout.ca/CellPhones/Guides/How-Much-Data-Does-Spotify-Use-Canada
- Hannula, Lauren. (May 2022). "How Much Mobile Data Do I Need?". *WhistleOut*. Retrieved from: https://www.whistleout.com/CellPhones/Guides/Mobile-Data-Usage-Guide.
- My GPS Tools. (March 2023). "How much data does Google Maps use per hour on iOS and Android?". Retrieved from https://mygpstools.com/how-much-data-does-google-maps-use-save-traffic.
- Netflix Help Center. "How to control how much data Netflix uses". Retrieved from: https://help.netflix.com/en/node/87.

5. Tools

Early in the project, we conducted exploratory data analysis using **Tableau**, but did not end up using any Tableau embeds on our website. Instead, we used **D3.js** in Observable notebooks to create the scatterplots in Section 1 as well as the interactive bar charts in Sections 3 and 4. The small-multiple radar charts in Section 2 were also plotted in D3.js using code from Ben Welsh and Nadieh Bremer, but traced and recreated in **Figma** so that we could add the dropdown menu interaction below each radar small multiple. We also used Figma to create the timeline and simulator cards in Section 4. Our website was created using Google Sites and consists of Observable and Figma embeds.

6. Usability Testing

Usability testing informed the final iteration of the site. With only three participants, our usability test feedback lacked breadth, but all our participants represented a key segment of our target user base, and so their feedback still provided valid inspiration for revisions to the site. The previous iteration of the site that participants reviewed is highlighted in screenshots below as well as in a full length screenshot here. The following documents our approach to usability testing, results, and how those results informed design revisions to produce the final site.

6.1 Approach

Participants

We conducted usability tests with three participants, all with different professional focus areas in product strategy and design: software engineering, UX research, and product management. We did not collect participant information related to age, gender, or ethnicity because our website is not designed for any particular age, gender, or ethnicity. Rather, our design is intended to appeal specifically to tech-industry professionals working primarily in the United States, so we selected participants for their current residence in the United States and their past experience developing or designing experiences for users. Although all participants currently live in the United States, only one has lived exclusively in the United States; the other two participants have lived in at least one other country (i.e. China, Korea, and Zambia). We hoped interviewing participants with a range of experiences living outside the United States might provide diverse reactions to and feedback on our design given the global focus.

Test Sessions

Sessions lasted 30-45 minutes over Zoom. Participants shared their screens as they navigated the site for the first time. We encouraged all participants to “think aloud” as they reviewed the site, sharing their thoughts, feelings, expectations, or confusion. We also prompted users to

share with us what they noticed first in each section and, if they had not already reflected, share what they thought the message of the section was before we moved on. Through observing their interactions with the site, we noted how effective elements of the site were in engaging and communicating the intended objectives to users.

6.2 Results

To analyze the test sessions, in addition to the notetaker's notes during the session, we re-watched recordings and noted observations and participant reactions for each participant by task/section and for each objective, each chart, time spent, overall notes, and overall recommendations. Since we found errors fell on a spectrum of more or less understanding and engagement, we decided to also allocate a score on a spectrum for each objective and chart. The scores provide a comparable, quantified summary of the success of each. The following highlights quantitative and qualitative results as well as revisions made to the site as a result of these results.

Quantitative Results

To quantitatively summarize the qualitative data, we scored the participant's ability to achieve each objective as well as engagement with each chart on a scale from zero to three based on the leveling below:

Score	Description
0	Failure: User didn't engage or grasp at all
1	Problematic: User had some understanding but substantial inaccurate interpretation or shortcomings
2	Adequate: User accomplished the goal enough for the main point to get across, but some shortcomings or confusing elements should be addressed to ensure broader success
3	Good: User accomplished goal

Figure 13. Rubric for scoring a participant's ability to achieve each testing objective

The scores help to highlight sections and charts which required substantial changes versus minor modifications as well as the reasons why. We recognized that the validity of the scores is especially limited given our small sample size but still found this a helpful exercise to explore the test results. Figure 14 shows all of the scores for the objectives and charts arranged by section. They quickly highlighted the weaknesses and strengths of the current design. For example, the Global Overview - Affordability chart was our highest priority to remove or substantially modify. Every participant had significant challenges understanding it. The Country

Focus - World Map was a close second for usability challenges. In contrast, the Country Focus - Radar Charts were easily understood and effectively accomplished the objective of engaging the participants. The Affordability charts were understandable but did not resonate and evoke empathy as much as we hoped. Similarly in the Connectivity section, while the charts were understandable and scored relatively high, the story they told was not as compelling to users as intended, and the objective of motivating empathy was not as strong as hoped.

Figure 14. Participant scores for each objectives and charts arranged by section

Participants completed a short pre- and post- survey, including a question which asked them to rank five elements of mobile app design and development in terms of importance, with high scores indicating greater importance and low scores indicating lesser importance. Participants ranked load time as the most important in the pre-survey, which suggests we had an apt audience for the connectivity/speed data. The score stayed steady for that element. Participants allocated more points to how much mobile data is required for loading the app/features in the post-survey, which is the other element we hoped to positively impact. Perhaps not an unsurprising result given how directly we communicated this point in the site, but it was still somehwat validating that the scores increased.

Rank the importance of the following elements in mobile app design and development:	Pre-Survey	Post-Survey	Pts. Change
How long it takes to load the app/features	14	14	0
How much mobile data is required to load the app/features	8	10	0.25
Visual accessibility (for example, color contrast)	5	6	0.2
Visual aesthetics / branding	10	9	-0.1
Language / localization	8	6	-0.25

Figure 15. Changes between Pre- and Post- Survey

Qualitative Results & Revisions

Section 1: Introduction

While participants grasped the overall purpose of the site and shared reasons they would be interested in it, their commentary highlighted areas in which it would be valuable to simplify the language and be more direct about the value proposition to viewers. The reference to the ISO's usability standards — effectiveness, efficiency, and satisfaction — was not recognizable to any participants, and so not a useful short-hand for explaining how these issues fit into UX.

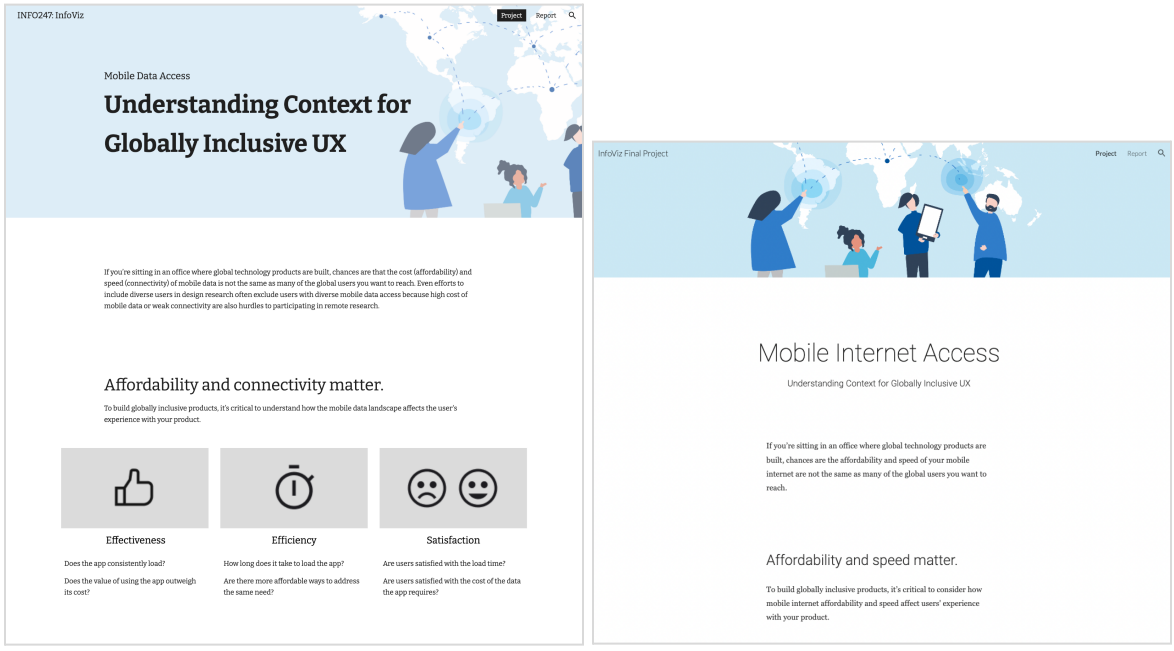


Figure 16. Screenshots of our introduction before (left) and after (right) revisions. The revised version is more concise and the probing questions were edited and moved to the end of the website.

Revisions

We extensively simplified the introduction to just a few sentences as a hook for the topic, so we could more immediately jump into the data to justify it. We moved the probes to consider how these issues affect users' experience in the viewer's products to the end of the site, as a final reflection after we have provided them with more data on the issues and why they matter. We organized these prompts by theme, affordability and speed, rather than the ISO usability standards.

Section 2: Global Overview

Participants easily grasped the bar chart and gravitated toward comparing extremes in it. The regional comparison was secondary and did not resonate with most participants. The box and whisker plot was the biggest failure of the design. Participants found a box and whisker unfamiliar, the income group organization distracting and unhelpful, and the affordability data point difficult to digest. However, participants were interested in seeing some global data following the theme.

Overall, while participants "believed" the text, they did not find the connection between the charts and the text immediately clear.

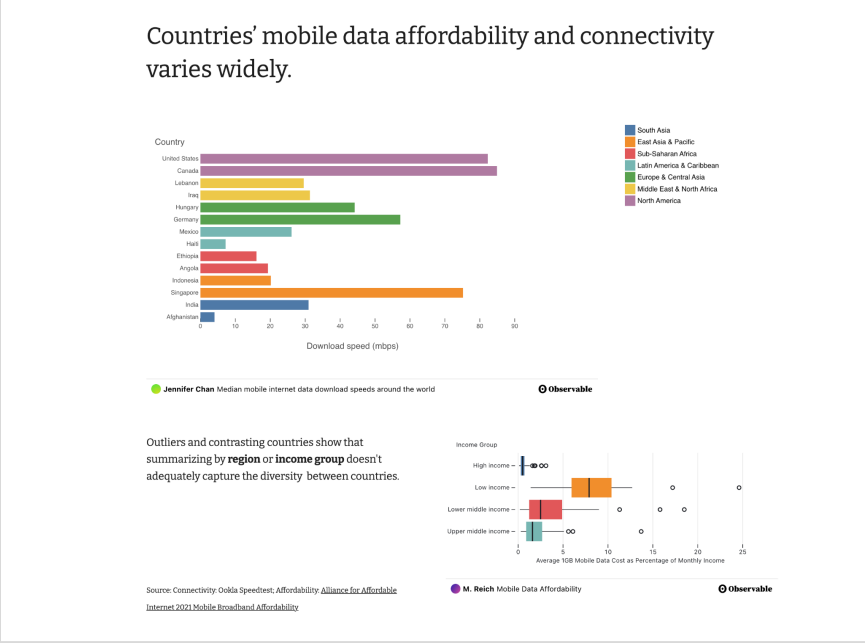


Figure 17. Screenshot of the global overview section before revisions

Revisions

We decided to maintain and expand on the global data given the interest in accessing it but iterated on how to simplify the themes and focus on highlighting extrema. We dropped regional or income group comparisons since they did not resonate and instead focused on demonstrating diversity and relevance of these issues by highlighting the number of countries

(points) in which they are more severe. We showed more countries in a concise way by including both key data points—speed and affordability—on repeated scatterplots with tooltips for exploration of individual countries only if viewers are interested. (See Fig. 18) We simplified the complex and high volume data by highlighting the relevant section of the charts, countries above the UN mobile internet affordability target and below the global mobile internet speed average. These annotations and highlights align closely with the surrounding text and respond directly to some of the questions raised in feedback sessions about why affordability and speed still matter even as infrastructure improves. After adding additional data and text, we iterated on the layout to provide a clear connection between text and visualization and sequence of information for each theme, which was a challenge for participants in the previous design.

Figure 18. Screenshots after revisions showing key data points (speed and affordability) on repeated scatterplots with highlights and annotations to direct the audience's attention to the main points.

Section 3: Country Focus

Participants grasped why we chose to focus on these five countries, but the pie chart and world map were unnecessarily difficult to read. The income group color channel did not add value to their interpretation.

The interactive radar charts were the most compelling to the participants of any visualizations in the design. They quickly understood the meaning and were able to use the overall shape as an indicator for context before comparing individual factors. For example, most participants started with identifying the United States as the biggest circle and then compared individual factors to guess the other remaining countries from there.

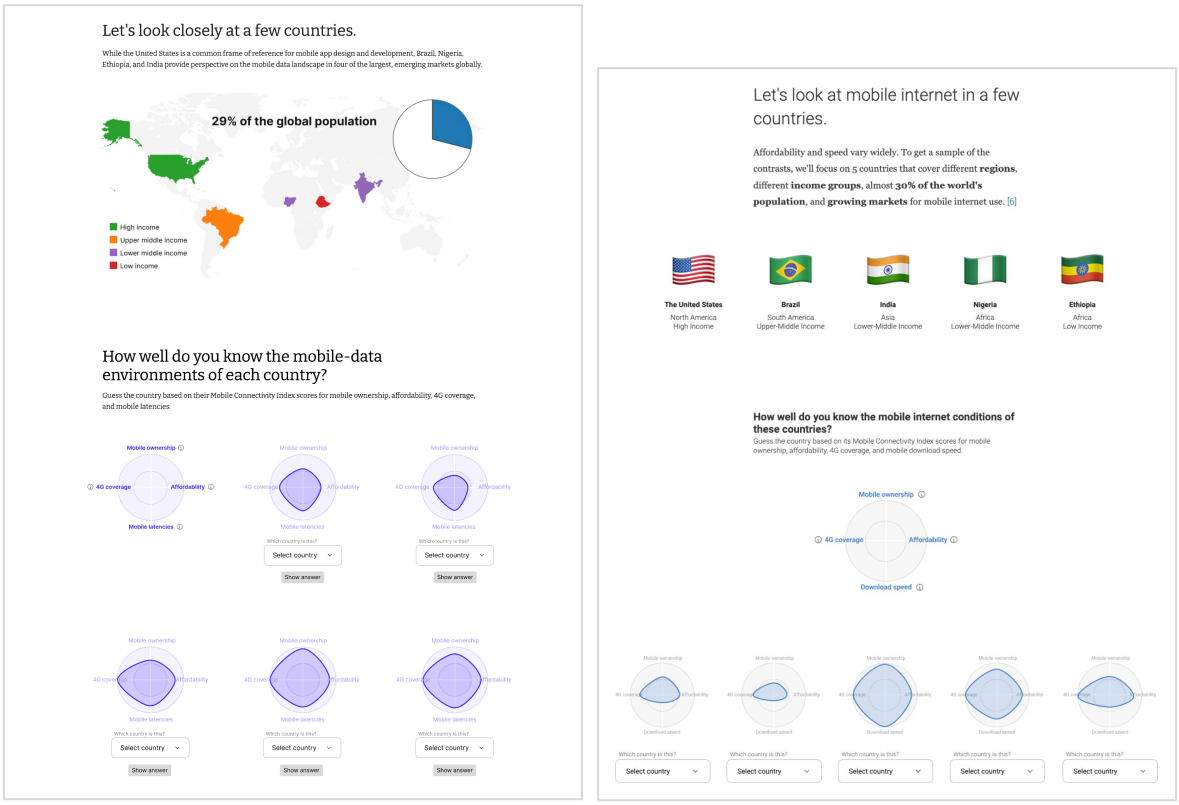


Figure 19. Screenshots of our Country Focus section before (left) and after (right) revisions, where we replaced the map with flag emojis and condensed the radar charts into one row.

Revisions

We eliminated the world map and pie chart and simplified the introduction of the five countries to emoji flags and text snippets. (See Fig. 19) Participants over indexed on the population size of the country as the reason it was selected as a focus in usability tests. While it was a factor, we balanced this information more in the current design by noting population in the overall description but focusing on the regional and income group variety in the snippet of text for each country.

At least one participant thought the two rows of radar charts might indicate an order or hierarchy, so we adjusted the layout to one row with charts organized in a way that makes the intentional lack of order more evident. The single row of radar charts should also facilitate even easier comparison. We changed the “latencies” axes to “download speed”, so that for all axes of the chart, it is clear that a higher number indicates better mobile internet.

Section 4: Affordability

All participants eventually accurately understood these charts and the interactive input inspired some reflection, but the data did not resonate as much as we hoped. In part, the complexity of understanding the indicator of affordability and the time frames — hours of consumption and income per month — were a lot to digest.

While we followed visualization best practices to keep the x-axis scale consistent across small-multiple charts, our users reacted negatively to the lack of visible data in the Google Maps chart and did not interpret the extremely short bars as a statement about the low data consumption of Google Maps as we intended.

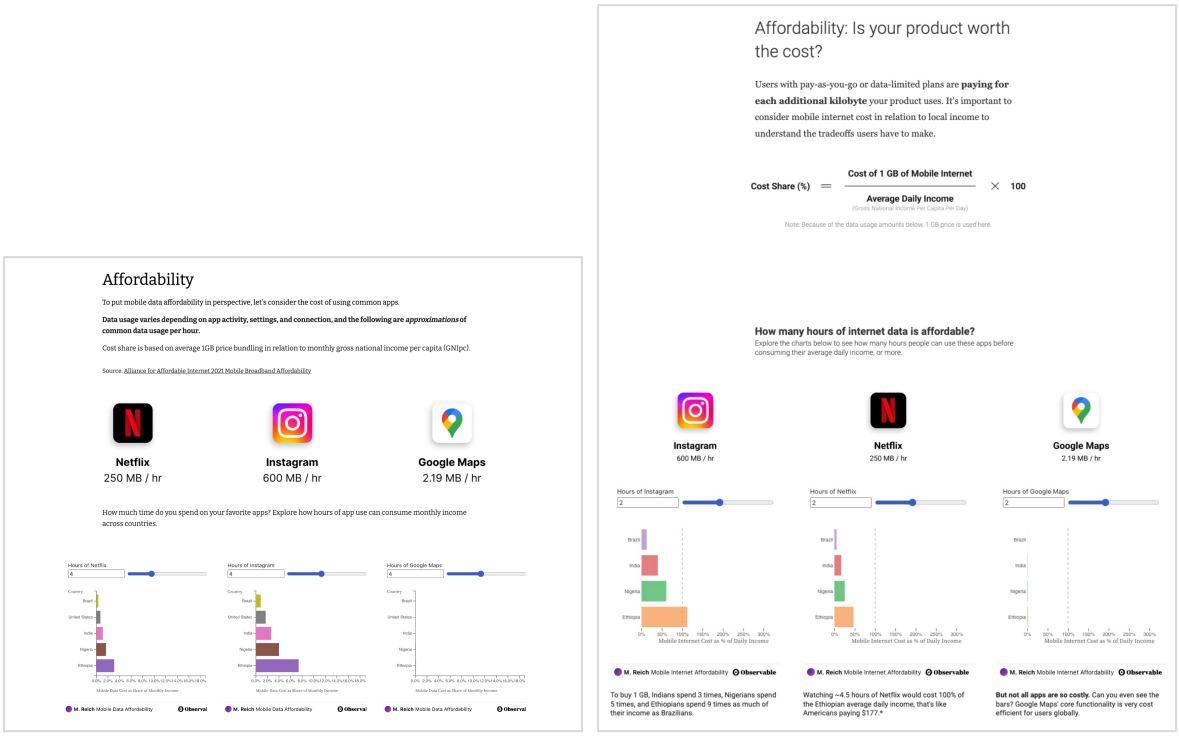


Figure 20. Screenshots of our Affordability section before (left) and after (right) revisions, where we added an image to explain the cost share ratio, a reference line, text annotations and more.

Revisions

We added an image laying out the cost share ratio since this data point is important but was difficult for users to grasp in sentence form. Based on a participant’s suggestion that app usage is typically tracked and considered on a daily basis for these apps, especially because of standard screen time trackers on mobile devices, we changed the affordability ratio from

average monthly income per person to average daily income per person in the denominator. In decreasing the time frame, we increased the cost share percentages, which we hope makes the numbers easier to digest and remember. With this adjustment, we reduced the maximum hourly input from 15 to 5 hours and the step of input from 1 hour to .25, or 15 minutes. We added a line at the 100% mark to emphasize this threshold since the charts are small, and it is unusual to see amounts past 100%. Finally, we added brief text snippets under each chart to highlight memorable data the user may notice, including breaking affordability down into ratios between countries, putting cost share in perspective of the US average daily income per day, and explaining that the Google Maps data is highlighted to show how efficient the app is.

Section 5: Connectivity

The download speed bar chart was another standout success across sessions. Users found the animation eye-catching, the chart easy to accurately understand, and particularly hung onto the text box summarizing the chart's takeaway—that in Ethiopia download speeds are 5x slower than the United States. Two participants even brought that specific fact up in their recollection of the site reported in the post-survey completed a day after their test sessions. However, no participants picked up on the 'losing signal' metaphor we attempted to convey through the animation and so perhaps we will reconsider changing the animation to make it more meaningful.

While we expected the app speed chart to be a bit challenging to understand, participants quickly grasped the circles as a minute each. Two of the three participants engaged in the comparison between apps without getting stuck in the complexity of how time spent manifests when speed is very fast or loading is asynchronous. However, the software engineer participant found the examples difficult to relate to because the apps are designed to include asynchronous downloads which reduces visibility of load times to users. The participant suggested that focusing on a synchronous task, such as downloading a file, may be a more realistic and accurate representation of the engineering.

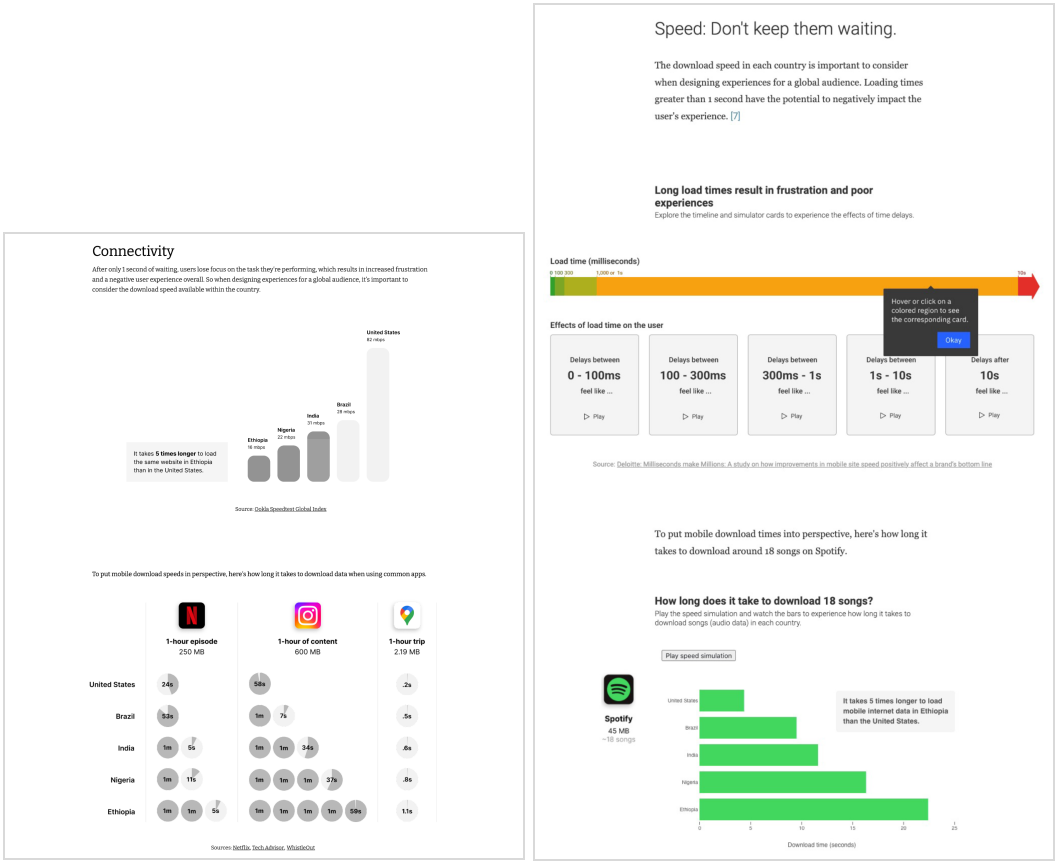


Figure 21. Screenshots of our Speed section before (left) and after (right) revisions, where we entirely redesigned our visualizations to include animation and simulate long load times in an effort to evoke empathy.

Revisions

Participants had a difficult time empathizing with how small wait times could make a huge difference in user frustration and overall experience. We responded to this with the addition of a new visualization drawn from Deloitte Digital's research on how milliseconds of waiting can cost brands "millions." (See Fig. 21) While the previous iteration had a reference to this data, viewers can now experience just how long 1 second or 10 seconds of load time feels relative to 100 milliseconds—something that several participants requested.

We also combined concepts for the first and second charts in the original design to adjust for three elements of participant feedback. Participants found the bar chart animation engaging but were unclear on whether the animation was actually representative of speed. They also commented that actual time may be more relatable than mbps and a simulation of time could help to digest the importance of this issue. Finally, as described above, a participant suggested that a synchronous app task, such as downloading files, may translate better to speed. In the revised chart, the data is converted to time and the animation simulates the time amounts shown. We adjusted the app data for perspective to downloading a Spotify playlist.

7. Distribution of Work

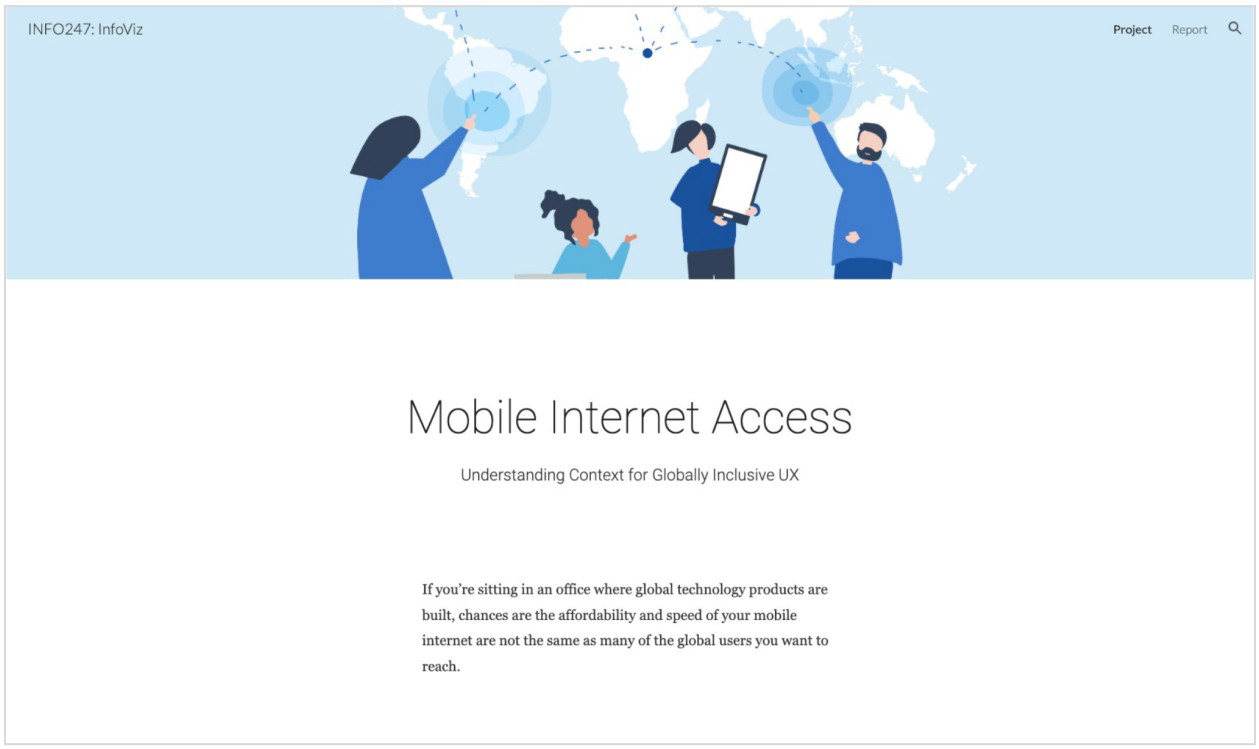
Category	Task	Jennifer Chan	Mary Grace Reich
Preparation	Background Research	30%	70%
	Data Processing	50%	50%
Visualizations	Section 1: Scatterplots	10%	90%
	Section 2: Country selection		100%
	Section 2: Small-multiple radar charts	100%	
	Section 3: Interactive bar charts		100%
	Section 4: Timeline and cards	100%	
	Section 4: Interactive bar chart	100%	
User Testing	Test design	50%	50%
	Testing	50%	50%
	Findings analysis	20%	80%
Final Website	Written content	40%	60%
	Visual styling	100%	
Final Report		50%	50%
Average contribution		**50%**	**50%**

8. Links to Data Repository and Visualizations

- Connectivity + Cost data spreadsheet for data processing
- Observable notebooks with interactive and animated visualizations
    - Scatterplots: Global Mobile Internet Affordability v. Speed
    - Small-multiple radar charts: Mobile Conectivity Index Enabler Scores Radar Charts
    - Interactive bar charts: Mobile Internet Affordability
    - Animated bar chart: Median Mobile Internet Download Times

- Figma file with wireframes and final designs for interactive visualizations
    - Wireframes
    - Load-time timeline and cards
    - Mobile Connectivity Index Enabler Scores Radar Charts

9. Additional Screenshots



Introduction section

Affordability and speed matter.

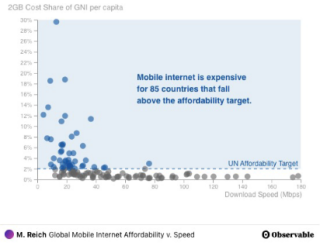
To build globally inclusive products, it's critical to consider how mobile internet affordability and speed affect users' experience with your product.

Affordability limits access.

As of 2022, **85 countries have not met the target** for mobile internet affordability, 2% of monthly income (GNI per capita) for 2 GB of mobile broadband internet. [1]

For people on pay-as-you-go and data-limited mobile internet plans, the standard in most low- and middle-income countries, **managing the cost** of using a product is an **ongoing calculation**. [2][3]

Many countries don't have affordable mobile internet.

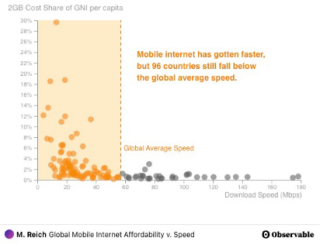


Speed limits satisfaction.

Mobile internet has gotten faster, but the web has also gotten more complex and requires more data to load. The average mobile internet **speeds increased by 60%** globally. [4] But during the same period, the median mobile web page **transfer size increased by 57%**. [5]

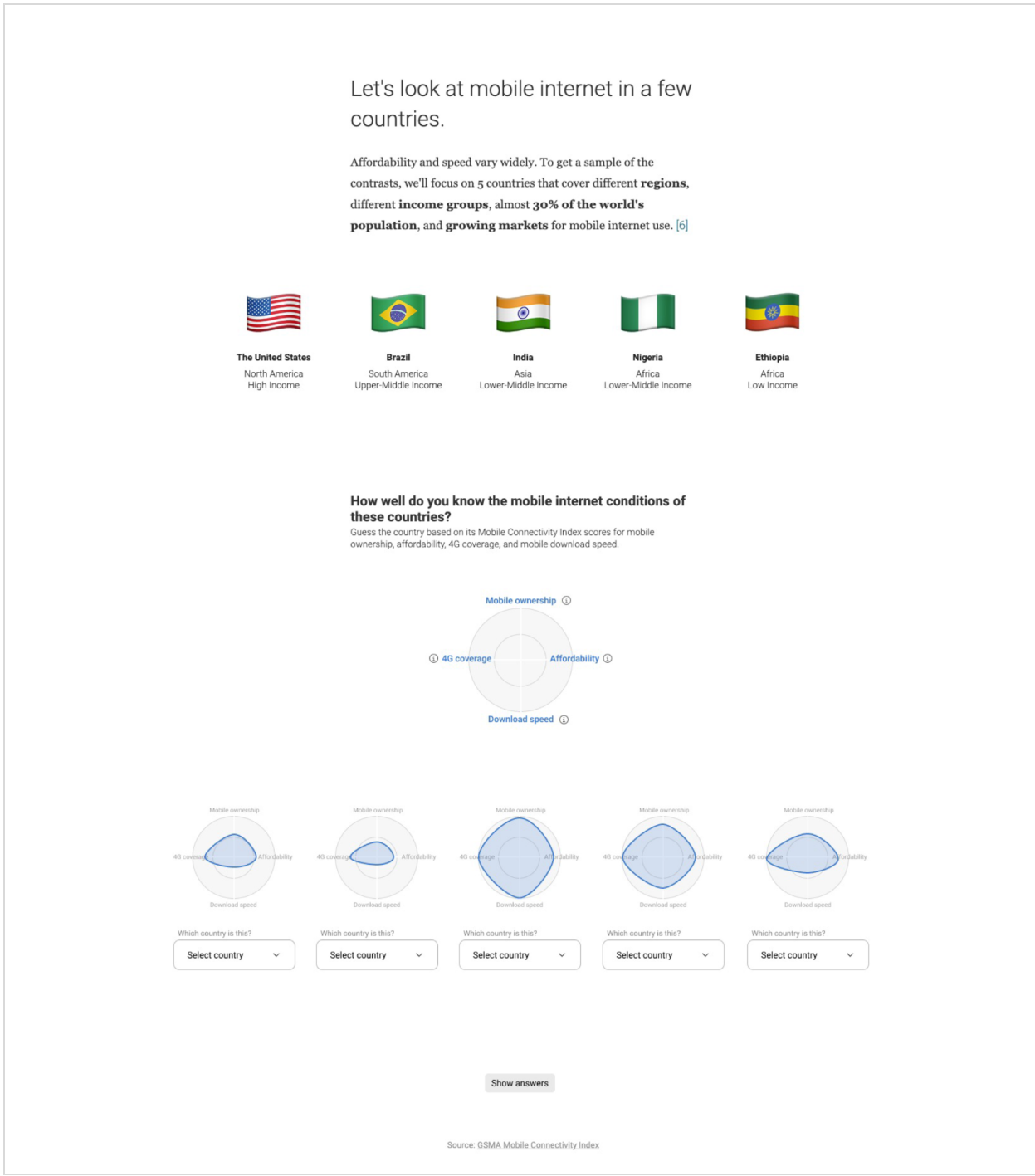
For users with a slower rate of improvement in mobile internet speed, the increase in internet complexity, and so data to download, is outweighing progress in mobile internet speed.

Many countries can't keep up with mobile data demands.



Note: Only countries with both speed test and 2GB cost data visualized. Sources: Ookla Speedtest Global Index, Alliance for Affordable Internet 2021 Mobile Broadband Affordability

Global Overview section



Country Focus section

Affordability: Is your product worth the cost?

Users with pay-as-you-go or data-limited plans are **paying for each additional kilobyte** your product uses. It's important to consider mobile internet cost in relation to local income to understand the tradeoffs users have to make.

$$\text{Cost Share (\%)} = \frac{\text{Cost of 1 GB of Mobile Internet}}{\text{Average Daily Income}} \times 100$$

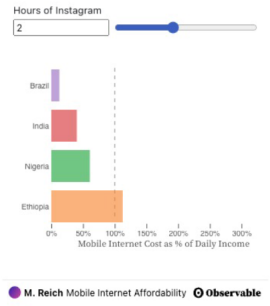
(Gross National Income Per Capita Per Day)

Note: Because of the data usage amounts below, 1 GB price is used here.

How many hours of internet data is affordable?

Explore the charts below to see how many hours people can use these apps before consuming their average daily income, or more.

Instagram
600 MB / hr



M. Reich Mobile Internet Affordability Observable

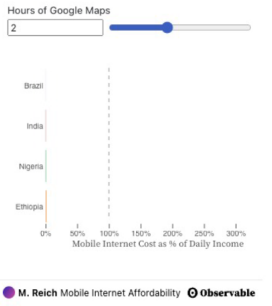
To buy 1 GB, Indians spend 3 times, Nigerians spend 5 times, and Ethiopians spend 9 times as much of their income as Brazilians.

Netflix
250 MB / hr

M. Reich Mobile Internet Affordability Observable

Watching ~4.5 hours of Netflix would cost 100% of the Ethiopian average daily income, that's like Americans paying $177.*

Google Maps
2.19 MB / hr



M. Reich Mobile Internet Affordability Observable

But not all apps are so costly. Can you even see the bars? Google Maps' core functionality is very cost efficient for users globally.

*Estimate based on US average GNI per capita per day, 2021

Note: Data usage varies depending on app activity, settings, and connection. Hourly data usage are estimates based on common usage. Because mobile internet per GB pricing is rarer in the United States, U.S. data is excluded here. Sources: Alliance for Affordable Internet 2021 Mobile Broadband Affordability, TechAdvisor, WhistleOut, Netflix Help Center, MyGPSTools

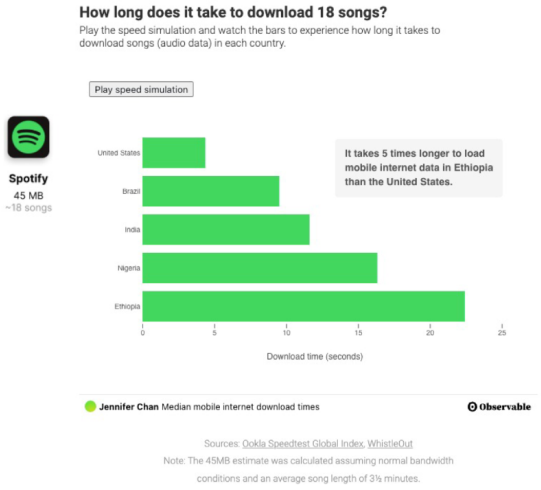
Affordability section

Speed: Don't keep them waiting.

The download speed in each country is important to consider when designing experiences for a global audience. Loading times greater than 1 second have the potential to negatively impact the user's experience. [7]

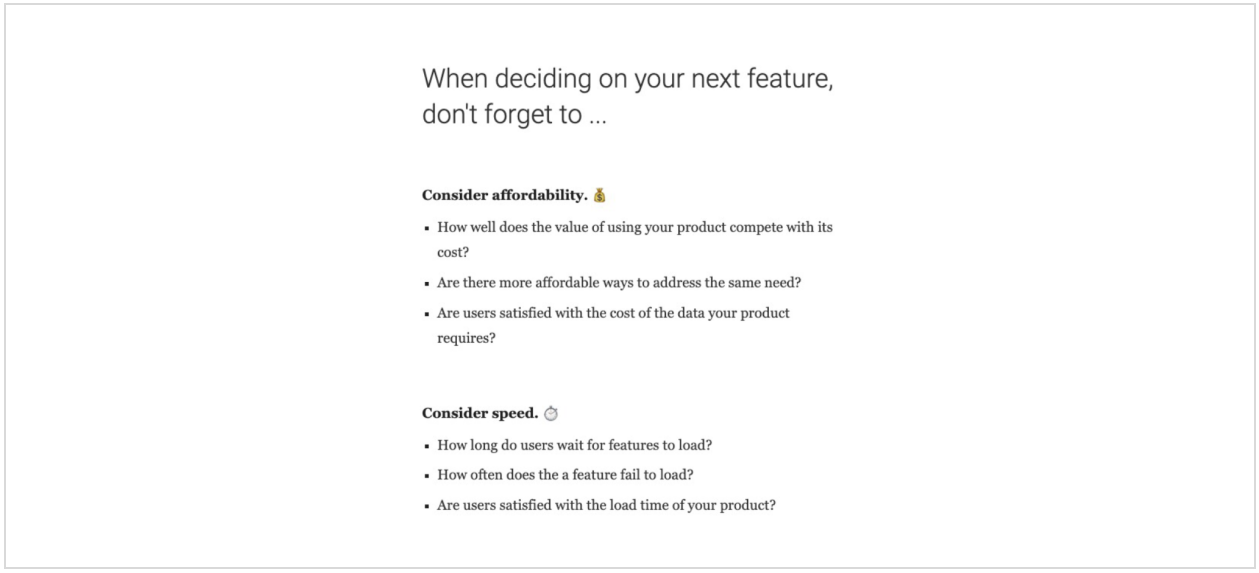
Source: Deloitte: Milliseconds make Millions: A study on how improvements in mobile site speed positively affect a brand's bottom line

To put mobile download times into perspective, here's how long it takes to download around 18 songs on Spotify.



Sources: Ookla Speedtest Global Index, WhistleOut
Note: The 45MB estimate was calculated assuming normal bandwidth conditions and an average song length of 3½ minutes.

Speed section



'Things for our audience to keep in mind' section