WHITEPAPER

CLOUDFLARE

Getting Faster: Know your website, and know what's slowing it down

Factors that impact web performance, and steps businesses can take to assess and improve the performance of their web properties.

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PART 1

Why is performance important?

A website or web application's performance directly impacts its ability to generate revenue.

This impact stems from several factors. Most immediately, a page that loads slowly or otherwise performs poorly will see worse user engagement — specifically, higher bounce rates and less time spent on pages. Similarly poor performance reduces conversion rates of various kinds. In addition, page performance is an important contributor to organic search rankings. And all of these factors present additional challenges in the context of mobile device experiences.

PART 1: WHY IS PERFORMANCE SO IMPORTANT?

USER ENGAGEMENT

Research shows that users are quick to abandon applications and websites that load slowly or fail to load altogether:

- The BBC discovered that 10% more site visitors left for every additional second it took for their webpages to load.[1]
- 39% of users stop engaging with a website if images take too long to load.[2]
- On mobile devices, 53% of visits to webpages are likely to be abandoned if the pages take longer than 3 seconds to load.[3]

Conversely, by improving page load speed on mobile, U.S. Express experienced a 15.65% reduction in bounce rates.[4]

CONVERSION RATE

Unsurprisingly, conversion rate improvements result in more revenue: Mobify saw an average yearly revenue increase of close to $380,000 as a result of their increased conversion rate.

- Conversions go down 7% due to just one additional second of load time.[5]
- Walmart saw a steep drop in conversion rates as load times increased from 1 to 4 seconds.[6]
- For Pinterest, a 40% reduction in perceived load times increased sign-ups by 15%.[7]
- Even improvements of a few milliseconds make a difference: Mobify found that reducing their homepage's load time by 100 milliseconds resulted in a 1.11% increase in conversions.[8]

ORGANIC SEARCH RANKINGS

Search engine optimization, or SEO, is the practice of making one's Internet property more visible by improving its ranking in organic search results. A higher ranking leads to more visitors — in fact, a Backlinko study found that the highest-ranked Google search result sees a clickthrough rate 10x higher than the tenth-ranked result, on average.[8]

A website's performance goes a long way towards determining its search ranking. In mid-2021, Google began incorporating Core Web Vitals — a set of high-priority web performance metrics — into its ranking algorithms. These Core Web Vitals are:

- **Largest Contentful Paint (LCP)**, which measures loading speed
- **First Input Delay (FID)**, which measures interactivity
- **Cumulative Layout Shift (CLS)**, which measures visual stability

While Google does not share the precise impact Core Web Vitals (or any other factor) has on search rankings, their public communications indicate that organizations should treat these performance metrics as important priorities.[9]

PART 1: WHY IS PERFORMANCE SO IMPORTANT?

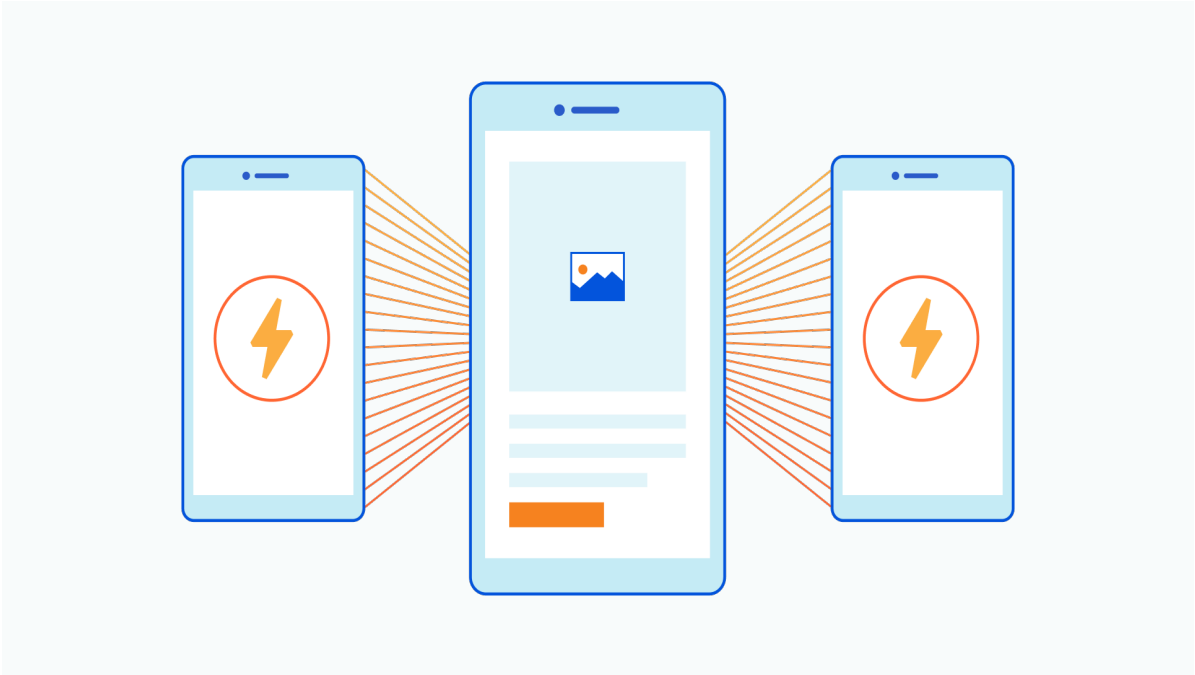
MOBILE DEVICE EXPERIENCES

Because mobile presents unique challenges compared to desktop, it should be considered a separate aspect of performance: a website or app must be specifically designed for mobile to ensure it will perform well on handheld devices.

Mobile devices have accounted for more Internet connections than desktop computers since 2016.10 And a Kleiner Perkins survey found that, on average, users spent 3.1 hours per day on mobile and 2.2 hours on desktop.[11]

Consequently, mobile performance is hugely important for businesses:

- 40% of Internet transactions occur on mobile devices.[12]
- Users abandon 53% of mobile sites if they take over 3 seconds to load.[13]



PART 2

What factors affect web performance?

The Internet today is not what it was even five years ago. Web pages and web applications are heavier and more dependent on external resources and services. Application backends are more complex thanks to the continued evolution of cloud technology and changes in Internet protocols. Users are accessing the Internet on a wider variety of devices than ever before.

As a consequence, maintaining performance has become more of a challenge than ever. Let's take an in-depth look at trends and factors that can impact website or application's performance:

PART 2: WHAT FACTORS AFFECT WEB PERFORAMNCE?

COMPLEX WEB CONTENT

Webpages have steadily increased in size since the Internet's inception. In 2021, the average desktop webpage had a total page weight of 2.2MB — more than a 4x increase from 2011[14]. As technology improves, users expect richer and more personalized user experiences that incorporate various types of media.

To keep users engaged, apps and websites today are adding more and more:

- **Rich media content:** such as video and high-quality images.
- **CSS:** Style sheets that impact the look and feel of a page.
- **JavaScript:** Dynamic webpages and personalized content are the norm. As a result developers include even more JavaScript that needs to render.
- **API calls:** Increasing API network calls that deliver content or additional functionality from multiple third-party sources.

While these changes make for the richer, more personalized experiences that users prefer[15], they can also make it more difficult to build Internet properties that load efficiently and respond quickly.

PART 2: WHAT FACTORS AFFECT WEB PERFORAMNCE?

INCREASED CONSUMER EXPECTATIONS AND THE USAGE OF MOBILE

Today's consumers are more connected than ever, which increases the demand on the backend infrastructure supporting websites and applications. Users connect to apps and websites from around the globe, on all kinds of devices. A 2016 Nielsen survey found that 57% of respondents who made an online purchase in the past six months bought from an overseas retailer.[16]

In addition, mobile is the new benchmark for web performance. But building websites for mobile users presents a new set of challenges. For one, mobile performance is constrained by network connectivity and availability. Despite the widespread availability of 4G and 5G networks in some countries, 60% of mobile connections worldwide take place over 2G.[17] And in some regions, mobile network providers will throttle bandwidth past a certain amount.[18] Adapting web pages for mobile also means screen real estate is a challenge. Webpages have to be designed so that they're still readable and usable on mobile.

Despite these challenges for developers, mobile users have high performance standards for their apps: one study by Dimensional Research found that 49% of users expect apps to respond in 2 seconds or less, 55% hold the app responsible for performance issues, and 80% indicated they will only attempt to use a problematic app three times or less.[19]

DNS

Before user devices can connect to Internet properties, the Internet property's user-facing name — its domain name — has to be translated into a machine-readable IP address. For this to occur, the user device has to query a DNS resolver that will map the domain name to the IP address and send the correct IP address to the device. This process takes time — and reducing that time is an important part of optimizing performance.

In addition to DNS lookups for the main domain name, other DNS queries may be necessary to load other resources on each webpage. For instance, if images are hosted on a different domain than yours, then loading a webpage will involve querying all those different domains in order to load the images. Multiple DNS lookups can add up to several seconds' delay in some cases.

DNS providers may not be optimized for speed. If a user's first stop is to a slow DNS provider a long way away, then it will take longer for your website to load.

Many DNS providers take over 50 milliseconds to resolve each DNS query, while the fastest DNS providers will resolve queries in under 20 milliseconds — **Cloudflare DNS**, for instance, resolves queries in under 12 milliseconds on average.[20]

ORIGIN SERVER HEALTH

Origin servers are the primary servers that process and respond to incoming client requests for a website or application's content. As websites and applications become more complex, they put a greater strain on origin servers. Slow origin server performance results in sluggish performance overall, even if the rest of a web property's infrastructure and content is optimized.

Research by the Nielsen Norman Group shows that response times should be no longer than 1 second in order to avoid interrupting a user's train of thought.[21] If a server cannot handle at least 1 request per second, the user will perceive the application as performing slowly.

In order to meet these thresholds, organizations should keep an eye on:

PART 2: WHAT FACTORS AFFECT WEB PERFORAMNCE?

Unevenly distributed server workloads

Over-utilized servers will run more slowly, adding unnecessary latency and impacting the user experience. If some servers have too much of a workload while other servers are under-utilized, the workload needs to be distributed more evenly across the serversin order to maximize performance.

The differences can be stark between an application with effective load balancing and an application without it. One SaaS company experienced a 2-3 second improvement in page load times after deploying **Cloudflare Load Balancing**.[22]

Server crashes

Like all computers, servers sometimes crash. A 2017 survey by ITIC Corp found that some servers experienced up to 37 minutes of unplanned downtime a year on average, while the most reliable servers — IBM Z Systems with Linux — were down for only 0.9 minutes per year.[23]

If there is no strategy in place for failover, server downtime can result in slower service for users, or a loss of service altogether.

NETWORK FACTORS

The Internet is made up of large interconnected networks. As data travels from one point to another, it may pass through any number of routers, switches, and networks to reach its destination. Therefore, a number of network factors can slow down or impact performance. Some of these factors are outside an organization's control, but others deserve careful attention:

Network conditions between servers and users

Users access Internet properties from all kinds of networks, and network conditions play a huge role in how well your website or app performs:

- Network latency is partially caused by distance. The farther a user is physically from an origin server, the more latency there will be. The speed of light is a hard limit on how fast data can travel, and data will take from a few milliseconds up to nearly a second to travel from the user to the server and back. (The effects of network latency can be somewhat reduced by using a CDN — content delivery network — to cache content closer to users.)
- Network congestion occurs when network traffic exceeds bandwidth at a certain point on the network, whether that's within an Internet Exchange Point (IXP), in a data center, or on a LAN router in a home. The resulting network congestion leads to slower Internet speeds for anyone connected to the network. Network congestion can be limited to a certain geographic area that lacks sufficient infrastructure, or it can affect an entire ISP's network.
- Mobile networks are often unreliable, although consumers increasingly rely on them for Internet access. The quality of service over a mobile network depends upon the user's location, the amount of bandwidth offered by their cellular provider, and many other factors. While mobile networks are improving around the world, some parts of the world still struggle with cellular reliability and connectivity.[24]

PART 2: WHAT FACTORS AFFECT WEB PERFORAMNCE?

Internet protocols that impact performance

Many protocols currently in use on the Internet were not built for the Internet as it exists today — specifically, its massive scale, enormous user base, and tremendous volumes of data in transit. The following protocols can cause web performance challenges:

- **TCP (Transmission Control Protocol)** is the primary protocol used on the web. This transport protocol involves a back-and-forth acknowledgement in order to open a connection between the client and the server. Once the connection is open, TCP ensures that the transmission is reliable by checking that all data arrives and is in order. This emphasis on reliability means that TCP is not the fastest transport protocol available — however, most of your website will reach users via TCP.
- **UDP (User Datagram Protocol)** is a much faster transport protocol than TCP, but it is also much less reliable. Unlike TCP, UDP does not open a dedicated connection between devices before transmitting data, and it does not ensure that all data packets arrive and are in order. UDP is extremely useful for video streaming, voice calls, and other use cases where speed matters more than reliability, but its usage is limited to these use cases.
- **HTTP** is an application-layer protocol, which means it is the protocol just beneath the surface of web applications. All user interactions are translated into HTTP requests that are sent to the origin server, and all server responses are also in HTTP. Newer versions of HTTP are faster and more efficient: HTTP/2, released in 2015, is faster than HTTP/1.1. If your website is still served over HTTP/1.1, users may experience slower performance than they would over HTTP/2.
- **TLS (Transport Layer Security)** is a protocol for encrypting Internet traffic and helping ensure that devices connect to legitimate servers. While TLS is absolutely necessary for security, especially as consumers depend more on the Internet, running older versions of the TLS protocol can slow down load times. The latest version of TLS, TLS 1.3, eliminates several steps in the protocol for a faster connection. (TLS is also known as SSL, which was the protocol's original name in the 1990s.)

PART 3

What steps can you take to assess and improve web performance?

No one strategy will address the performance challenges identified in Part 2 of this paper. To better understand their website or application's strengths and weaknesses, organizations should consider the following steps:

PART 3: WHAT STEPS CAN YOU TAKE TO ASSESS AND IMPROVE WEB PERFORAMNCE?

RUN A SITE SPEED TEST

How a site performs in a local testing environment is not a good indication of how it will perform for users across a variety of network conditions.

Website speed tests aim to simulate real-world conditions and provide data on how well a website actually performs. The best website speed tests should let you know not just how fast their site or application is, but also what aspects of it are slowing performance.

Speed tests can provide a variety of metrics, including:

- **Load time:** how long it takes for a web browser to finish downloading and displaying the webpage
- **Time to First Byte (TTFB):** how long it takes for the browser to receive the first byte of data from the web server
- **Requests:** the number of HTTP requests that a browser makes in order to fully load the page

For more speed test performance metrics, see Appendix: Performance Metrics to Know.

WebPageTest.org is a well-respected and thorough free testing platform. Google PageSpeed Insights can also help you assess your website.

Additionally, Cloudflare offers a simple testing tool for assessing load time, TTFB, and total requests.

ASSESS ORIGIN SERVER HEALTH AND LOAD

Monitor server health

Server performance can degrade for a variety of reasons: Server hardware can break down, or server software may become outdated, for instance. The average lifespan of a server is about 5 years.[25] Servers should be monitored constantly to ensure their health and availability.

Check server load

If origin servers are overloaded, they will perform slowly. Check the memory utilization of your servers. Are some machines working harder than others? Are some servers using all of their compute power while others aren't? To get the most performance out of your servers and utilize server resources efficiently, it's important to balance workloads across multiple servers.

Offload some content requests via caching

If every user request has to be fulfilled by the origin servers, they may become overloaded. By implementing caching — in the browser, at the network edge (using a CDN), or both — many, if not most, round trips all the way to the origin server can be eliminated.

PART 3: WHAT STEPS CAN YOU TAKE TO ASSESS AND IMPROVE WEB PERFORAMNCE?

IDENTIFY WHERE SITE TRAFFIC COMES FROM

One of the principal causes of network latency is distance, so the location of users matters a great deal.

For instance, it takes longer for Internet traffic to travel the nearly 16,000 kilometers from New York to Sydney (80 ms) than to travel the 4,000 kilometers from New York to San Francisco (21 ms).[25] If a website is hosted in the U.S. but most of its users are in Sydney, then those distant users will experience slow performance.

Google Analytics is a helpful tool for determining where users are coming from geographically. Once you've identified where site traffic comes from, you can figure out whether or not your web property's infrastructure is set up to serve those locations effectively.

AUDIT AND OPTIMIZE SITE IMAGES

A user's browser needs to download images before they can be displayed. The larger an image is (in terms of file size, not dimensions), the longer it takes to download. Large images often add to the load time of a webpage unnecessarily, as many devices don't have good enough screen resolution or a large enough screen to make very high resolution images necessary.

Before images can be optimized, you should determine how many images your website has and where they are located by conducting an image audit. Following the audit, as many images as possible should be optimized — meaning, compressed, resized, and converted to a lossy file format such as JPEG. Optimized images will load much more quickly.

Moz.com has step-by-step instructions for crawling all images on your website, identifying which ones need to be optimized, and optimizing them. Screaming Frog's SEO website crawler is helpful for auditing website images.

There are many free image optimizer tools available online. Adobe Photoshop can also compress images and export images in a variety of formats.

Cloudflare **Image Resizing**, **Mirage**, and **Polish** are the best options for companies that already deploy the Cloudflare CDN in order to cache images for faster delivery. Cloudflare Polish can be activated in the Speed tab of the Cloudflare Dashboard.

PART 3: WHAT STEPS CAN YOU TAKE TO ASSESS AND IMPROVE WEB PERFORAMNCE?

CHECK THE CURRENT PERFORMANCE OF YOUR DNS PROVIDER

Identify your DNS provider, and then find out if your provider is giving you the best performance possible.

One of the best resources for measuring DNS performance is DNSPerf. DNSPerf regularly tests all authoritative DNS providers and public DNS resolvers. Their results and rankings are available for free at dnsperf.com.

To further improve your users' DNS experience, they can install Cloudflare's free DNS resolver service, 1.1.1.1, for a faster, privacy-first solution.

CHECK USER ISP NETWORK PERFORMANCE

Users may experience slow performance for reasons that have nothing to do with the website or app they are using. ISP network performance plays a huge role in the user experience.

A network speed test tool can help users identify issues with their ISP on their own. Cloudflare developed speed.cloudflare.com to help users make sure they are getting the network performance they should be getting from their ISP.

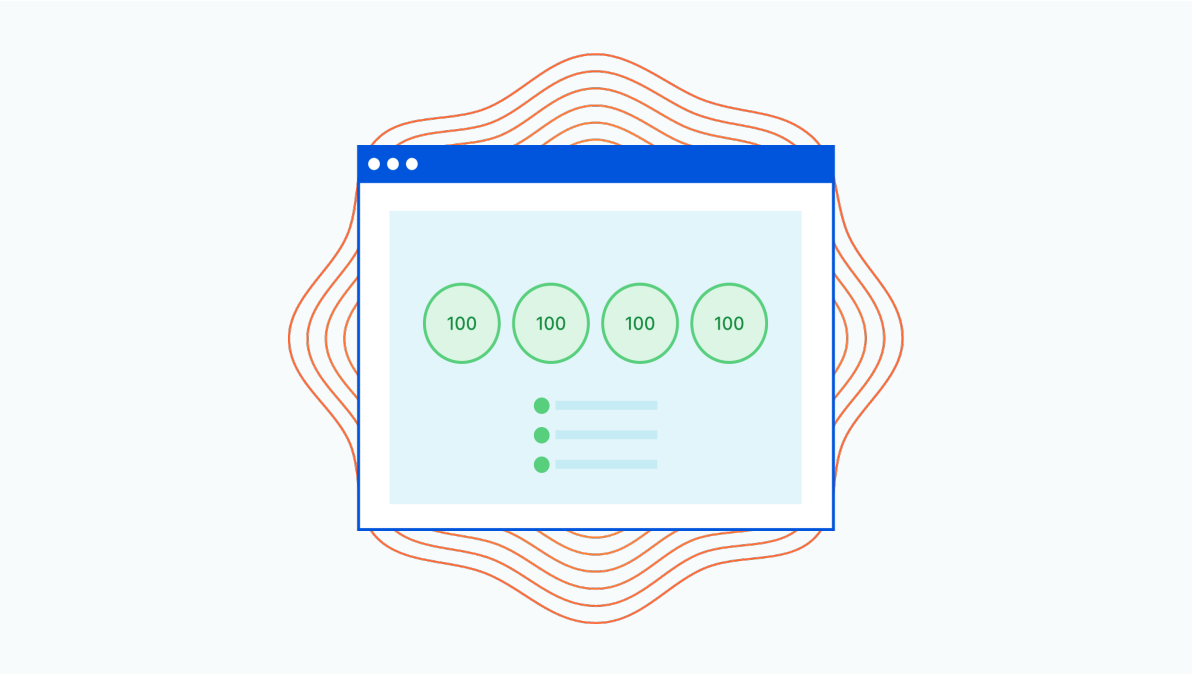
PART 4

How Cloudflare solves performance issues

Cloudflare's network of data centers spans hundreds of global cities. Each data center supports the full stack of Cloudflare performance and security services, ensuring that users and websites everywhere get the same performance and security benefits.

From fast web address lookups to accelerated delivery to the origin server, Cloudflare speeds up traffic at key points in its journey between servers and users.

PART 4: HOW CLOUDFLARE SOLVES PERFORMANCE ISSUES



DNS AND ISP ISSUES

Cloudflare is one of the world's fastest and most reliable authoritative DNS providers.[21] Cloudflare provides fast and secure **managed DNS** as a built-in service on its network. Cloudflare also offers 1.1.1.1, which is a public DNS resolver that keeps DNS queries private.

For consumers, **Cloudflare Warp** accelerates Internet access from mobile handsets. The Cloudflare Speed Test at speed.cloudflare.com helps users assess their ISP network's performance.

NETWORK

The **Cloudflare CDN** spans a global network of data centers that cache content closer to users so that requests don't need to travel long distances to origin servers. Cloudflare optimizes network traffic speeds in several ways.

Meanwhile, **Argo Smart Routing** delivers dynamic web content over the fastest network paths available, resulting in noticeably faster delivery and improved user experience.

Cloudflare supports the latest web standards and protocols, including HTTP/2 and QUIC (HTTP/3) for faster application layer data transmission, TLS 1.3 for more efficient SSL encryption.

Cloudflare supports the use of Signed Exchanges with Google AMP, providing native URL attribution when viewed in the AMP viewer.

PART 4: HOW CLOUDFLARE SOLVES PERFORMANCE ISSUES

CONTENT OPTIMIZATION

Cloudflare offers a number of image optimization features, including **Image Resizing**, **Polish**, and **Mirage**. Image Resizing allows customers to optimize images by resizing, cropping, compressing, or converting them to WebP, a newer image format designed for fast loading. Cloudflare also enables parallel streaming of progressive images to speed up delivery of multiple images on a page.

Video is hugely important for user engagement, and Cloudflare has several products and features for optimizing video. **Cloudflare Stream** is an online video platform for streaming media, and **Stream Delivery** ensures videos stream as fast as possible. Cloudflare offers **Concurrent Streaming Acceleration** for live streaming content as well.

Prioritization, or the order in which the assets on a webpage are loaded, makes a huge difference to page load speed. **Rocket Loader** from Cloudflare optimizes the prioritization of any assets that need to load before on-page JavaScript can execute. Cloudflare also supports HTTP/2 Prioritization in order to control how page assets are prioritized, avoiding the slower default prioritization of most browsers. BinaryAST for JavaScript is supported by Cloudflare to speed up JavaScript parsing so that it executes faster–crucial for the performance of dynamic or personalized webpages.

SERVER HEALTH AND AVAILABILITY

Cloudflare Load Balancing provides local and global load balancing to reduce latency, either by load balancing traffic across multiple servers or by routing traffic to the closest region. It also includes health checks with fast failover to rapidly route visitors away from failures.

Serverless computing has great potential for creating faster, more responsive apps than ever. **Cloudflare Workers** allows developers to build serverless applications that run on Cloudflare's network, closer to your users. Applications built with Cloudflare Workers are always available, with low-latency responsiveness. And **Cloudflare Pages** is front-end web development platform using the JAMstack (Javascript, API, and Markup) model to deliver similarly fast performance.

CONCLUSION

Website and application users want faster, more personalized interactions when they log on or pull up an app. It's possible to build such experiences if you use the right tools. Cloudflare helps accelerate millions of Internet properties, enabling companies to offer their customers the best possible experience.

To learn more, visit cloudflare.com/performance.

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APPENDIX: PERFORMANCE METRICS TO KNOW

Load time: The time it takes for a web browser to finish downloading and displaying the webpage (typically measured in milliseconds).

Time to First Byte (TTFB): How long it takes for the browser to receive the first byte of data from the webserver (measured in milliseconds).

Requests: The number of HTTP requests for resources that a browser has to make in order to fully load the page.

DOMContentLoaded (DCL): This measures the time it takes for the full HTML code of the page to be loaded; images, CSS files, and other assets don't have to be loaded.

Time to above-the-fold load: 'Above the fold' refers to the area of a webpage that fits in a browser window without a user having to scroll down.

First Contentful Paint (FCP): The time at which content first begins to be 'painted,' or rendered, by the browser. This can be any aspect of the page, including text, images, or non-white background colors.

Page size: The total file size of all content and assets that appear on the page.

Round trips: This metric counts the number of round trips necessary to load the webpage. When an HTTP request travels all the way from a browser to the origin server, and the server's HTTP response goes all the way back, this constitutes a round trip.

Render-blocking round trips: A subcategory of round trips. 'Render blocking' refers to resources that have to be loaded before anything else can be loaded.

Round trip time (RTT): The amount of time the round trips take.

Render-blocking resources: Certain resources, like CSS files, block other parts of the page from being loaded if they are not yet loaded. The more render-blocking resources a webpage has, the more chances there are for the browser to fail to load the page.