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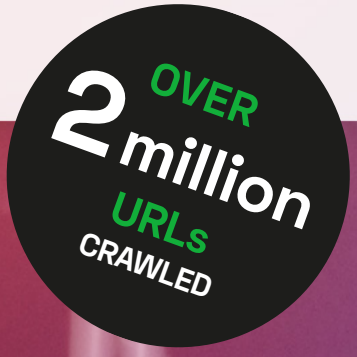
CORE WEB VITALS

Study – April 2021

Less than 4% of websites passed all Core Web Vitals tests. Is yours one of them?

BY
MARCUS TOBER | TOM WELLS | ABHISHEK THAKUR



Why this study

At Searchmetrics, our passion lies in helping businesses thrive in search engines. As a result, we have compiled this study to help businesses, SEOs, UX designers and web developers understand, with facts, what Core Web Vitals is about and what it means for the websites they manage.

While the Core Web Vitals update is not due to be released until mid-June[1], we wanted to get a sense of how websites are performing now. This comprehensive analysis enables us to provide real performance benchmarks, insights and guidance ahead of the Core Web Vitals update.

Also, we know that technical SEO topics are often difficult to explain to non-SEOs. We believe that a study like this can support technical experts in their effort to explain to non-experts why paying attention to Core Web Vitals matters and why it needs resources.Having a study like this on hand when attempting to explain the importance can help to make this a little bit easier.

As a result of this study, we have no doubt about the importance of Core Web Vitals over the long-term.

It is our pleasure to present this study to you so that you too can thrive in organic search and be prepared for the next evolution coming this year.

If you are looking for support with SEO for your business, please get in touch with one of our consultants to learn more about how we help businesses not only survive but thrive in the search engines.

GET IN TOUCH!

About Searchmetrics

Data-driven Marketers value Searchmetrics for its ability to deliver the predictable success that enables them to reach their search and content goals. Searchmetrics, its partners and clients are united by a belief in the power of insight and an understanding that data makes decisions better.

A bias towards innovation has helped Searchmetrics support the growth of household names like eBay, Zendesk and Siemens, giving them the power to navigate the hyper-competitive search landscape. Worldwide, thousands of businesses have already benefited from working with Searchmetrics and its comprehensive portfolio of data, software and services.

Founded in 2005 as a boutique digital agency, Searchmetrics has grown into a global provider of data, software platforms and expertise that drive online revenue and elevate brands.

As a company, Searchmetrics fosters an environment where executives and employees alike are encouraged to develop long-term solutions that tackle the challenges of the online world. The company is doing this by delivering customer-focused products and results-driven consultancy that create tangible value for their clients.

Searchmetrics offers four core software products, integrated into one platform, the Searchmetrics Suite, and tailored to each customer's needs.

- **Research Cloud:** Providing a single source of truth for SEO and market metrics.
- **Search Experience:** Connecting search and content achievements to company KPIs.
- **Content Experience:** Enabling the production of predictably successful content.
- **Site Experience:** Establishing priorities for improving technical website performance.

Searchmetrics' software is backed up by its services division, the **Digital Strategies Group.** Expert consultancy teams leverage the power of the platform to develop and implement sustainable strategies for clients and maximize their business potential.

With **Searchmetrics Insights**, the company is furthermore delivering a market research subscription service that affordably scales to a depth and breadth normally out of reach for most companies.

More information: www.searchmetrics.com.

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Main researcher and author of this study, Marcus Tober, Founder and Chief Evangelist at Searchmetrics.

Marcus is one of the pioneers who established SEO as a marketing discipline and the founder of Searchmetrics back in 2005.

In his position now as Chief Evangelist, he is responsible for highlighting the ever-increasing importance of SEO and providing guidance on how the discipline should develop in the future, both internally and externally. He has a cross-departmental strategic role: he advises on developments and trends in SEO and supports the product team in driving innovation in the Searchmetrics Suite.

In 2016, Marcus was voted European Search Personality of the Year at the European Search Awards. A self-proclaimed data and statistics geek, he is a frequent speaker at conferences and is often asked to comment on the latest trends in the industry.

Author of this study, Tom Wells, creative marketing expert.

Tom is a creative marketing expert focusing on emerging technology, SEO and AI. He is fascinated by telling stories with data and works with some of the leading names in the tech world.

To deepen his understanding of machine learning and AI, he is currently pursuing a Master's in Data Analytics from Georgia Tech.

Abhishek Takhur is a Data Scientist.

Abhishek is a world-leading data scientist and has many years of experience in the industry. He was also the first person in the world to achieve the status of Quadruple Grandmaster on Kaggle.

Who this Study is Written For

Business Leaders

While much of this study is technical, what it can do is to point out where your team of web developers, UX designers and SEOs need your help with focus and resources. It can offer tangible performance benchmarks that can function as concrete quality assurance targets.

Core Web Vitals are an excellent indicator of user experience. Improving these metrics will improve the overall user experience on your website. If your team does not get the chance to focus on these Core Web Vitals metrics, there could be a risk to your business once Google rolls out Core Web Vitals as ranking signals in mid-June this year.

As a business leader, you can use the data in this study to back up your decisions to invest additional resources or refocus your team. These findings and benchmarks can remove the guesswork when deciding on where to invest time and money in website development and SEO.

Key Insight for Leaders: The main finding in this study relevant to leaders is that websites that currently rank well in Google tend to have higher Core Web Vitals (and related Web Vitals) scores. We believe this trend will continue as Google continues to place more emphasis on user experience.

Marketers & Conversion Rate Optimizers

The ultimate goal of most marketing campaigns is conversions. User experience can have a dramatic effect on the overall conversion rate. Slow loading landing pages create a frustrating user experience causing a higher bounce rate.

Core Web Vitals provide a simple and effective way to benchmark user experience. They can be used to help design more effective marketing campaigns and optimize conversions. This study offers CWV benchmarks so you can see how you stack up compared to the competition.

Key Insight for Marketers and CROs: There is a lot of opportunity for improvement in terms of CWV scores. Most websites do not perform well. Emphasizing user experience in your next marketing campaign could give you a competitive advantage.

SEOs

SEOs will find that this study is the most comprehensive, data-driven study on Core Web Vitals that has been published so far.

We crawled over 2 million URLs analyzing not only the three Core Web Vitals metrics, but an additional 12 metrics and ranking factors to offer a fuller picture of web performance.

This study offers a snapshot of how websites are performing ahead of the Core Web Vitals update in June. It can help SEOs understand the Core Web Vitals landscape and gauge where there are opportunities for performance gains.

Key Insight for SEOs: The average performance of the majority of websites crawled is generally lower than Google's CWV benchmarks. While this may mean that Google will not be able to punish websites en masse that have failing Core Web Vitals performance, it offers an amazing opportunity to boost rankings as outperforming other websites is currently a very realistic goal to achieve.

Web Developers

Web developers can get a sense of key performance hurdles in terms of page loading time and interactivity. By understanding the effect certain web design practices may have on user experience, web developers can design with a greater knowledge of performance limiting factors that not only help the user but can also increase performance in the search engines.

Key Insight for Web Developers: While a web page should have visually appealing qualities, there is a balance to strike between design and user experience. Our data shows that too many plugins and render-blocking resources can create code bloat and severely reduce page performance.

UX Designers

UX designers can gain a better understanding of key factors that can cause poor user experience. Our data and examples offer key insights into how to create a better experience for your users.

Key Insight for UX Designers: The visual stability of many web pages, as measured by Web Vitals such as CLS, is quite poor, on average. Our findings also show that many web pages are slow to become interactive: this means the user has to wait a long time before being able to click, scroll or interact.

Students

Anyone who is currently studying SEO, Data Processing Technology, Computer Science, Computer Programming, Web Analytics, UX, Web Design, or Web Development would serve themselves (and their future employer) well to understand the findings and advice in this study.

In addition, understanding how this study was put together is a great way to learn what standard and level of detail would be expected at a corporate level.

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Need some help figuring all this out? Get in touch.

Searchmetrics will support you and your team with your website performance. You will work with highly experienced SEOs who not only understand Core Web Vitals, but the full spectrum of search.

Support Includes:

- Reporting and analysis of how your domain compares to competitors in your specific market.
- Identify areas of opportunity at scale, revealing page types that need to be prioritized and fixed quickly for maximum short-term performance improvements.
- Monitor SEO and Content performance and impact over time.

Contact us for help before your competition does.

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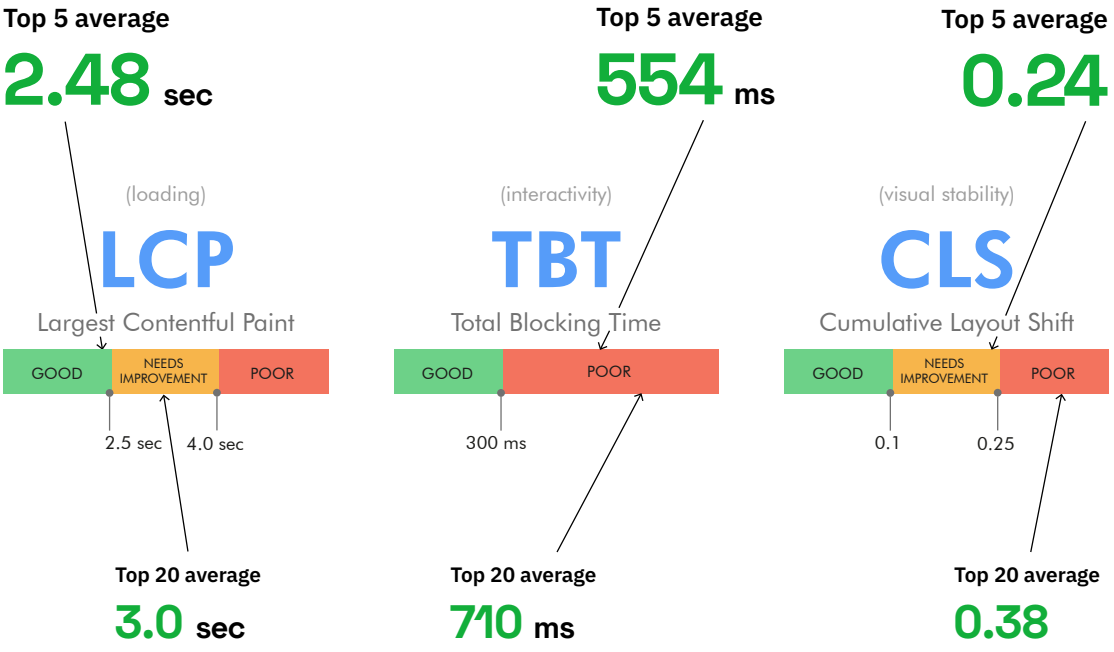
Executive Summary

We crawled over
2,000,000 URLs

96%
of all websites did not achieve a good score in all 3 Core Web Vitals*.

4%
only achieved a “good” CWV score.

* Based on desktop data. Less than 10% of all mobile sites saw a good score in all three Core Web Vitals.



In May 2021[2], Core Web Vitals will officially become ranking factors in the Google Search algorithm.

"Web Vitals is an initiative by Google to provide unified guidance for quality signals that are essential to delivering a great user experience on the web." – Google[3]

"A gradual rollout will begin in mid-June 2021." - Google[4]

So why is Google doing this?

According to Google, this update has two main purposes:

1. **to increase Google's emphasis on user experience. In simple terms, if a user has a good experience on a webpage, Google aims to rank this page higher.**
2. **to make it simpler for website owners and businesses to understand website performance and improve the user experience.**

But this seemingly simple update has got the SEO and web industry buzzing. It has thrown up many hotly debated questions such as:

- **How do I interpret my Core Web Vitals scores?**
- **Do I need to change anything on my website to get ready for this update? If so, what?**
- **How well are competitor websites performing in terms of CWV? What benchmarks should I aim for?**
- **Are other ranking factors interconnected with my Core Web Vitals score?**
- **How easy is it to optimize websites created with builder/CMS platforms such as WordPress or Wix?**
- **Do Google's entities such as YouTube perform well in Core Web Vitals?**

To offer comprehensive answers to these questions, we crawled **over 2 million URLs,** crunched the numbers, and performed correlation analysis across the top 20 organic Google search positions.

As well as the three Core Web Vitals, we looked at **12 additional related ranking factors** to offer deeper insights into what websites are doing well and where

Using real-life best and worst-case examples, we highlight some core areas where websites could benefit from healthy speed gains and UX improvements. they are falling short.

The Current State of Web Development: Technology vs User Expectations

To understand the philosophy behind Core Web Vitals, it's first important to understand where we are now. **We live in a world where users want to enjoy high-quality content as smoothly as possible on wherever they are.** But are websites delivering?

We all know how frustrating it is to quickly search for a news article only for the page to take forever to load; when you finally get there and scroll or click on something the page shifts as an ad banner tries to sell you something. Not ideal.

The Google Core Web Vitals update is in many ways a response to websites not living up to user expectations. It's a clear message to website owners that not putting users first may have a negative effect on rankings.

What is causing poor web performance?

Many websites are still not delivering on their mobile-first promise. We found that typically only the top 2-3 ranking websites achieved a good score in most Core Web Vitals metrics. This would indicate that a lot of websites still have some work to do in terms of user experience. But why is this?

Website Building Technology

One reason is that website building platforms such as WordPress and Wix have not really caught up with user expectations. While such website builders

are easy to use on the surface, they can be tricky to optimize under the hood. Often, web pages designed using these templates load all scripts, stylesheets and code blocks even if they are not needed. This can cause what is known as code bloat – where unnecessary code is loaded on a webpage causing slow page loading times.

Plugin-centric Web Economy

The logic of a platform like WordPress is also plugin-centric. This means that if you need to do something beyond adding basic content, such as optimizing images or lazy loading below-the-fold content, then you will need to use a plugin. These plugins are quick solutions but often add extra code to your website that can be hard to optimize.

Ad Space and Dynamic Content

Another key cause for poor user experience is dynamic content. Dynamic content like ads can cause a lot of layout shift if not properly implemented. The same is true for newsletter opt-in boxes and any dynamic content.

Tech Needs to Catch Up with User Expectations

So, while it seems Google is attempting to make its performance metrics more transparent, platforms and CMS systems like WordPress, Squarespace and Wix need to work together with businesses to help make it easier to optimize website performance.

Core Web Vitals as Tangible Performance Benchmarks for Web Developers

When developing a website, metrics such as Core Web Vitals can help set performance targets for your web developers to meet. As a business, this can be an effective method of quality assurance. By setting clear performance goals that are easily measurable with tools like Lighthouse, you can manage web projects more effectively and benchmark performance objectively.

Core Web Vitals Explained

Core Web Vitals are an extension of Google's page experience signals:

"Page experience is a set of signals that measure how users perceive the experience of interacting with a web page beyond its pure information value." – Google[5].

These signals include mobile-friendliness, safe-browsing, HTTPS, among others. They assess how positive or negative the user experience is for a webpage. For example, if a website is considered not mobile-friendly, it is quite likely that mobile users will not have a great user experience.

With Core Web Vitals, Google aims to measure real-world user experience for loading performance, interactivity, and visual stability of the page.

There are three Core Web Vitals metrics:

Largest Contentful Paint measures the render time of the largest image or text block visible within the viewport. The key idea is to provide a simple metric that shows how quickly a page's main content loads.

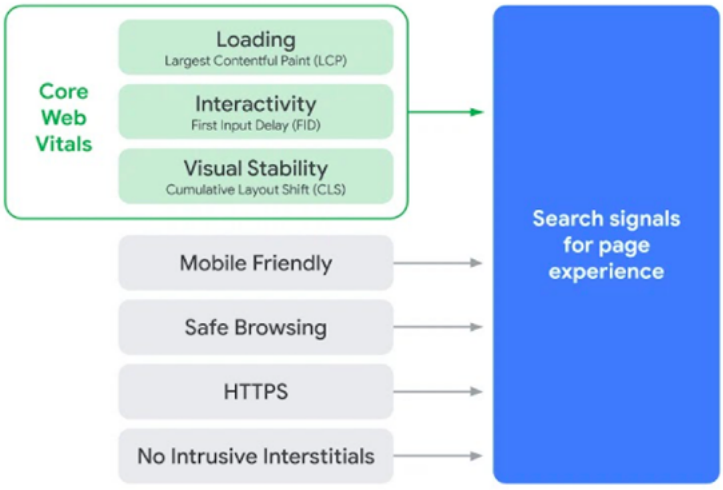


Image source: Google

First Input Delay measures when a user first interacts with the page. In this study, we have chosen to use Total Blocking Time as a proxy for FID. This is explained here in this document in more detail.

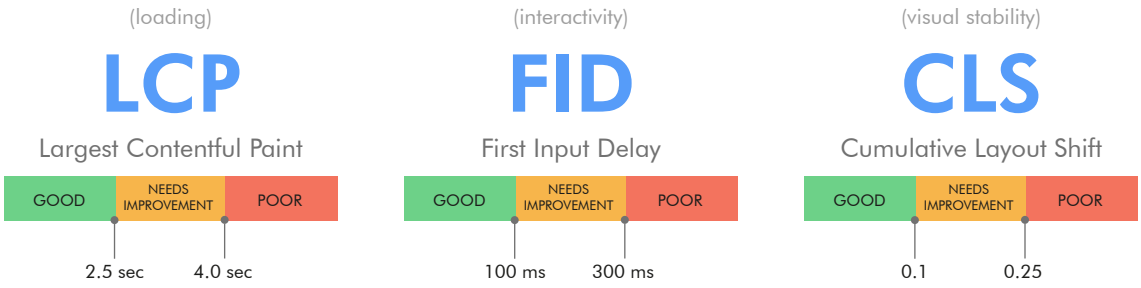
Cumulative Layout Shift is a score that measures how much content shifts during page rendering. A lot of content shift creates a negative user experience

Where to Check Your Core Web Vitals Score?

There are many tools available that can help you measure your Core Web Vital scores such as the Chrome User Experience Report, PageSpeed Insights, Search Console (Core Web Vitals report), and the Lighthouse Audit[6].

Core Web Vitals Benchmarks

So, what does "good" performance mean in numbers?



Largest Contentful Paint (LCP): To provide a good user experience, LCP should occur **within 2.5 seconds** of when the page first starts loading.

First Input Delay (FID): To provide a good user experience, pages should have an FID of **less than 100 milliseconds.**

Cumulative Layout Shift (CLS): To provide a good user experience, pages should maintain a CLS of **less than 0.1.**

But is getting a good rating really enough? What if your competitors have better CWV scores than you? To find out if high-ranking websites exceed the performance benchmarks set out by Google, we conducted an in depth analysis of the data.

The Complete Set of Web Vitals

"While the Core Web Vitals are the critical metrics for understanding and delivering a great user experience, there are other vital metrics as well." – Google[7]

Before we move on to look at the data, it's important to note that Core Web Vitals are a subset of metrics. They evolved from the Web Vitals initiative created by Google. **This means there are other Web Vitals that Google considers important.**

Google states that metrics like First Contentful Paint (FCP) are vital for diagnosing loading experience issues, while metrics like Total Blocking Time (TBT) and Time to Interactive (TTI) help gauge interactivity.

We believe that using other metrics in combination with the three Core Web Vitals paints a fuller picture of your web performance. Therefore, in this study, we have expanded this analysis to include 15 metrics in total.

Core Web Vitals
Data Analysis

We crawled over 2 million URLs for the regions USA, UK and Germany. In this version of the study, we mainly focus on the US data. The corresponding UK charts and stats can be found in the appendix of this study. The results for Germany are published as a standalone study.

For each keyword, **we analyzed the performance of the selected metrics across the top 20 organic Google rankings.** Position 0 is the featured snippet position.

Desktop vs Mobile Data

We examined both mobile and desktop results in this study. However, we believe that the desktop values provide more accurate benchmarks to aim for. The values for Google's mobile performance are based on simulated data that is throttled or slowed down[8]. As such we have observed much higher values across our metrics for the mobile data.

Due to throttling, we do not think that this is a true reflection of the state of mobile performance and as such place emphasis on the desktop results. While we provided the top 5 and top 20 average scores for mobile results, the desktop data will be the main focus of this study.

How were the metrics selected?

We selected the 15 performance metrics based on two criteria:

1. The impact this metric could have on Google search rankings.
2. Whether this metric could be realistically optimized by web developers.

Largest Contentful Paint – time for largest image/text block to load.

- Total Blocking Time as a proxy for **First Input Delay*** – total time of tasks that stop the user from interacting with the page.

***Why did we choose Total Blocking Time over First Input Delay?**

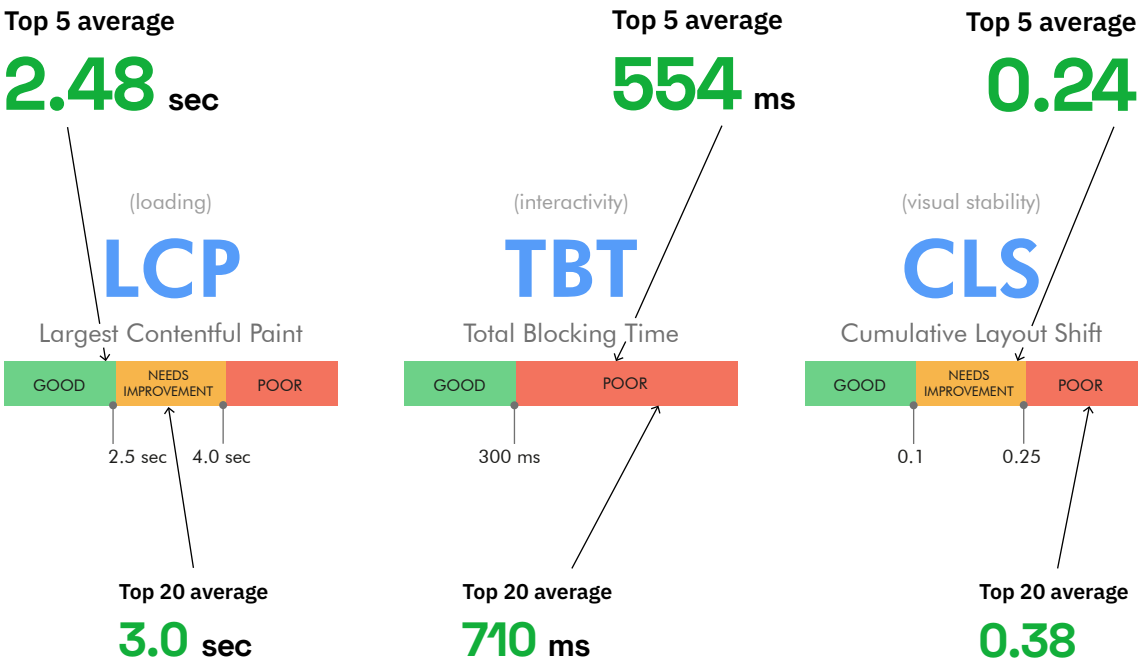
First Input Delay is a Core Web Vital. However, if a user does not interact with the page at all, the value for this metric will be 0. We found that many of the FID values were very low due to the vast number of null values. Rather than filter these out, we chose to measure TBT because it's a metric for which every URL has a value. It measures how many long loading tasks stop the user from interacting with the page. It is also known as a good proxy for FID: "Total Blocking Time (TBT) metric is lab-measurable, correlates well with FID in the field, and also captures issues that affect interactivity." – Google[9]

- **Cumulative Layout Shift** – a score of whether a page stays fixed, or elements jump about while loading.
- **First Contentful Paint** – FCP measures how long it takes the browser to render the first piece of content after a user navigates to your page.
- **Time to Interactive** – the time it takes for the page to be completely interactive.
- **Speed Index** – Speed Index measures how quickly content is visually displayed during page load.
- **Unused CSS Rules** – how much time websites could save by eliminating unused CSS.
- **Unused JS** – how much time websites could save by eliminating unused JS.
- **Next-gen Images** – load time you could save by using next-gen image formats such as WebP, JPEG 2000 and JPEG XR.

- **Optimized Images** – potential load time savings by correctly optimizing images.
- **Responsive Images** – potential load time savings by using responsive images.
- **DOM Size** – the number of DOM elements (HTML elements) on a page.
- **Render Blocking Resources** – how much time a website could save by eliminating unnecessary resources that stop the page loading.
- **Total Byte Weight** – the total file size of all assets necessary to load the webpage.
- **Number of tasks over 50ms** – the number of loading tasks that take 50ms or longer to complete.

Key Findings at a Glance

Core Web Vitals



<Code Bloat is slowing websites down>

On average sites could save almost one second by removing unused JavaScript.

1 sec

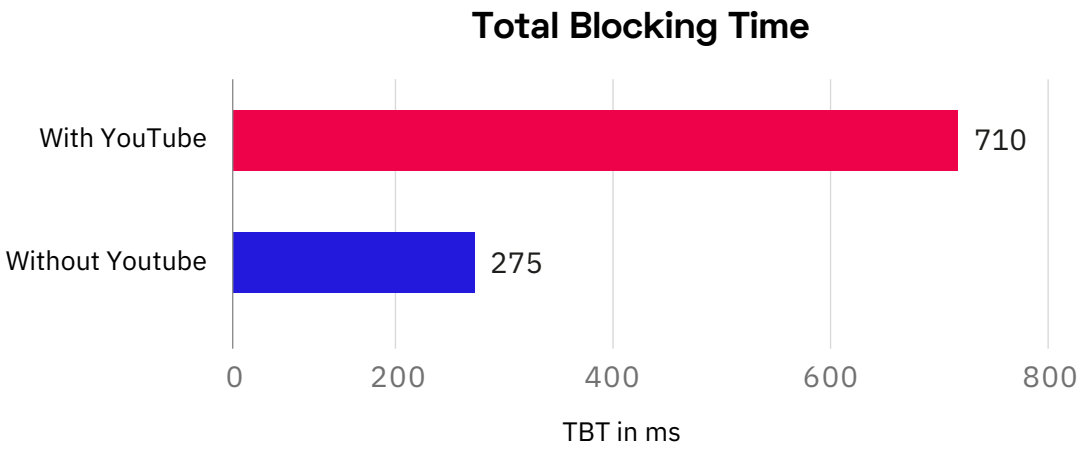
Optimizing images improves performance

286 ms
is the load time websites could save on average by using WebP images.

196 ms
is the load time websites could save on average by using responsive images.

96 ms
is the load time websites could save on average by optimizing images.

The Influence of YouTube



YouTube performs poorly across most metrics but still ranks highly.

Source: fyv6561 / Shutterstock.com

Core Web Vitals Correlation Analysis

To get a sense of the data, we first calculated the correlation coefficients for each performance metric. This value gives an impression of whether a good score in the selected metric is associated with good page rankings.

Correlation Explainer

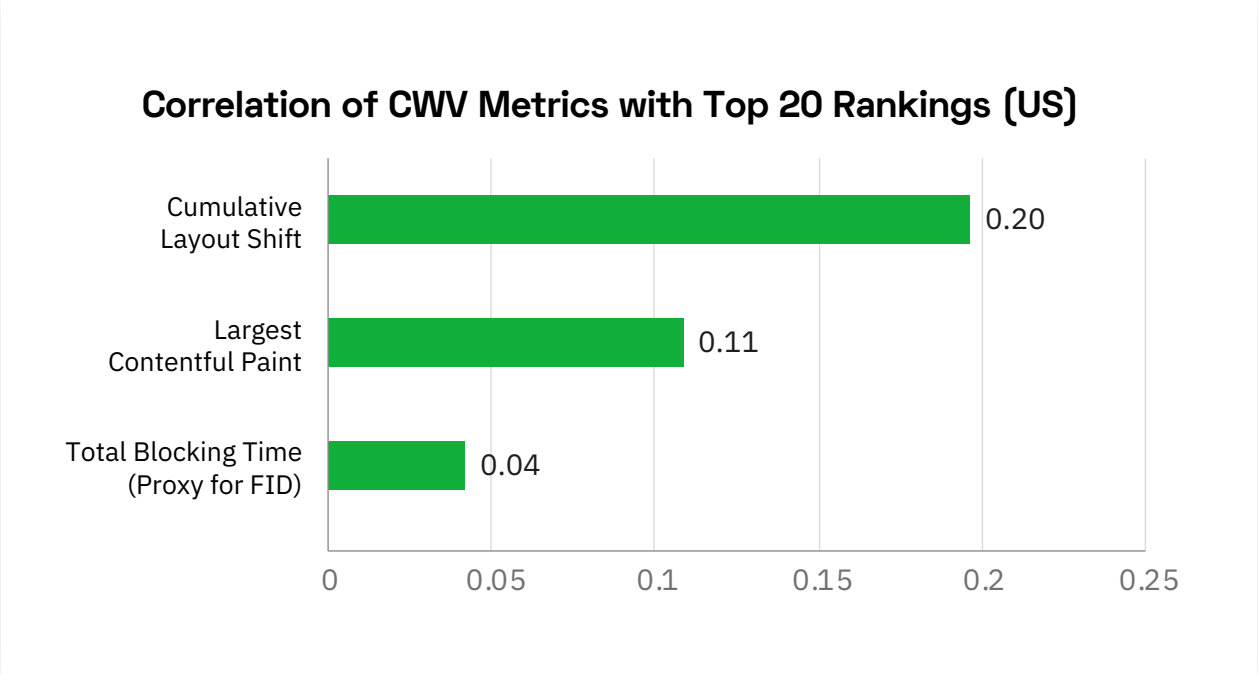
Correlation = how likely it is that a value increase/decrease of a metric will lead to higher rankings. Values range between -1 and 1. In our case, a positive correlation value means that a lower value leads to better rankings.

For example, if a page loads quicker, we would expect it to rank higher. As so many different factors can affect a page's ranking, a correlation value of 0.1 or above is reasonably high.

Correlation ≠ Causation – Correlation does note state that improving a score in a metric will definitely lead to an increase in rankings, only that it is associated with a good page ranking.

Correlation Analysis of Core Web Vitals

Starting with the three Core Web Vitals (with TBT as a proxy for FID), we can see that all CWV metrics have positive correlation coefficients, ranging from **0.04 to 0.20**.



We should note that Google has not yet officially included the Core Web Vitals as part of the search algorithm. However, it is logical to conclude that websites that perform well in these metrics offer a good user experience and thus rank highly.

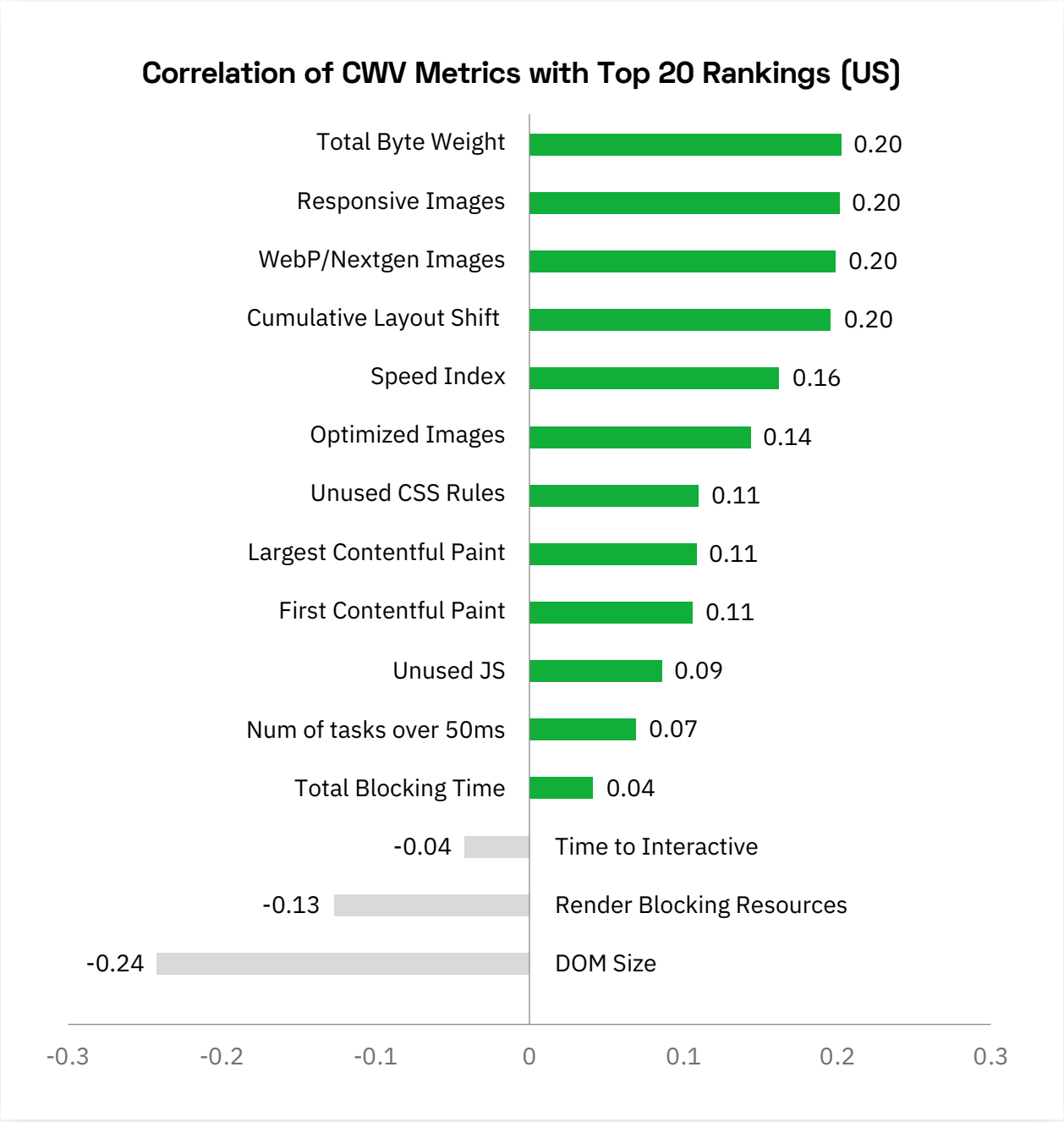
After the official update from Google is rolled out in mid-June[10], these metrics may have more influence on page rankings. In that case, we would expect these correlation values to increase post-update.

Correlation Values Across All Web Vitals

Expanding this correlation analysis to our full set of metrics, we can see that the metrics Total Byte Weight, Responsive Images, WebP Images and Cumulative Layout Score (CLS) have the highest positive correlation values. It's interesting to note that three of the top six metrics are related to images. Images are often overlooked and are a key area for optimization:

"For many sites, images are the largest element in view when the page has finished loading. Hero images, large carousels or banner images are all common examples of this." – Google[11]

Clearly, there are many potential speed gains for asset-heavy websites. Optimizing image size would also decrease the total size of a web page (Total Byte Weight) which could partly explain the positive correlation.



What about negative correlations?

We can see that three metrics – Time to Interactive, Render Blocking Resources, and DOM Size – have negative correlation values. So, does this mean that websites with lots of render-blocking resources rank higher?

A closer look at the data reveals that there are certain asset-heavy websites like YouTube that, despite slow load times, still rank highly. One explanation

could be that Google partially ignores negative page loading metrics as long as the user signals such as click-through rate and time on page are positive enough. A perfect example of this is YouTube, where loading times are found to be slow in general.

The general finding is that good Web Vitals scores do correlate with higher rankings.

Core Web Vitals Rankings Analysis

Next, we calculated the performance of the top 20 ranking web pages for each of the selected metrics across the keyword set. This analysis offers an insight into how the top 20 websites are performing compared to each other and compared to Google's benchmarks.

We have also calculated the average scores across the top 5 and top 20 positions. Comparing these values gives a sense of whether top rankings web pages get better Web Vitals scores.

Largest Contentful Paint (LCP)

The Largest Contentful Paint (LCP) metric reports the render time of the largest image or text block visible within the viewport. To provide a good user experience, websites should strive to have Largest Contentful Paint occur within the first 2.5 seconds of the page starting to load.

So how many websites hit this benchmark?

Looking that the top 20 ranking websites across our dataset, only the first 3 positions are below this threshold. One explanation for the peak from positions 4-9 is that some asset-heavy websites with relatively poor LCP performance are still ranking well.

We discuss the influence of websites like YouTube in more detail in the YouTube section of this document.

Largest Contentful Paint (LCP) Results

Top 5 average

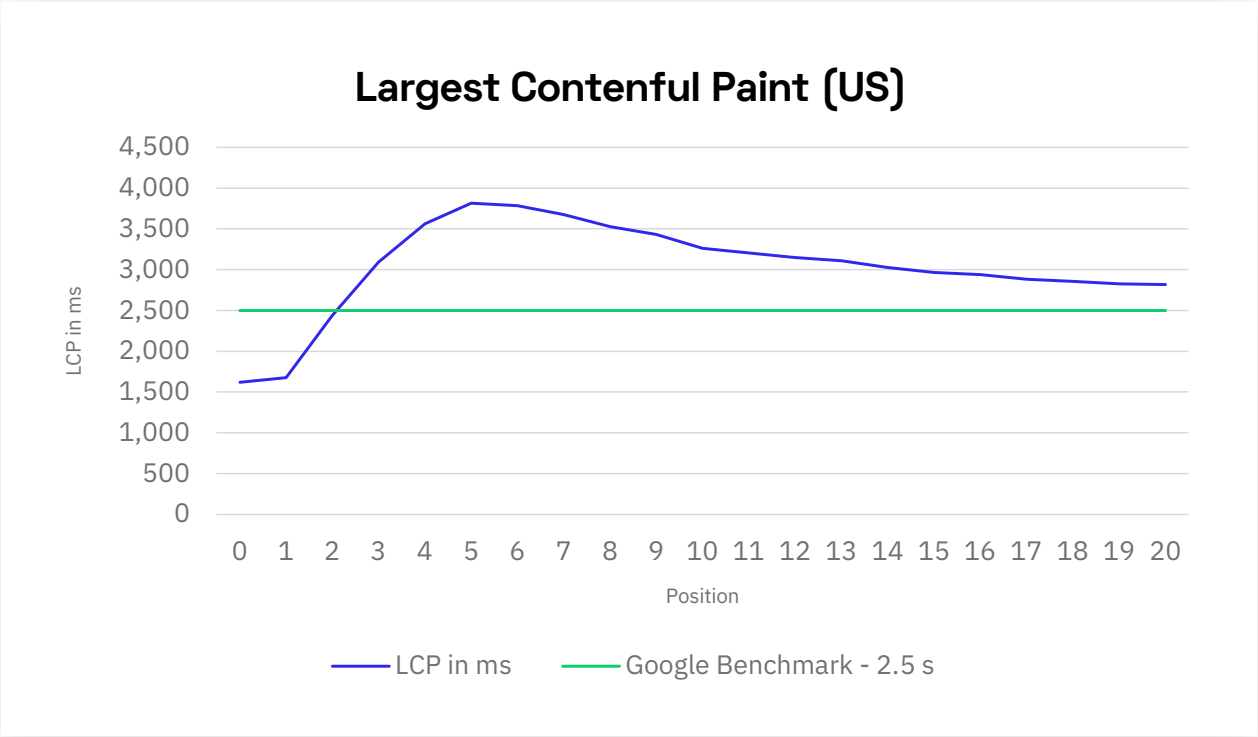
2.48 sec 3.26 sec

0.9% faster than Google's benchmark of 2.5 seconds.

Top 20 average

3.00 sec 3.22 sec

21.3% slower than Google's benchmark.



Worst Case Example: Khan Academy

Online e-learning platform Khan academy had quite a few pages with LCP times of over 10 seconds, some more than 20. Their e-learning platform features primarily video content. However, this content is slow to load which makes for a poor user experience. This website could reduce its LCP by loading a static image in place of the full video and deferring the video load until the rest of the page has been rendered[12].

Best Case Example: Wikipedia

Wikipedia favors a lightweight approach to web design, using mainly text and optimized images. This results in the online encyclopedia scoring low in LCP across many web pages, in the region of 0.4-0.6 seconds for a typical entry.

Tips to improve LCP

- Try to understand on a page level what the largest element is that needs to be loaded, usually an image or video asset.
- Optimize this asset using responsive design or next-gen image formats (WebP, JPEG 2000, JPEG XR).
- Try to use a leaner template with fewer plugins if possible.
- Reduce render-blocking resources such as CSS and JS.

Total Blocking Time (TBT)

We are using TBT as a proxy for FID as explained in the introduction. Effectively, TBT measures if anything on the page prevents the user from interacting with that page.

It does this by adding the time taken for long tasks – according to Google[13], a page loading task that takes more than 50ms. A task is any server request required for rendering a web page.

For example, a task includes retrieving stylesheets, scripts images, videos. Typically, the larger the asset, the slower the response time and the longer this "task" takes to complete.

If a user tries to interact with a page, they may notice lags or delays if there is a high TBT.

For Total Blocking Time, we observe a similar pattern to LCP, where only the top 2 ranking websites are below the threshold for a "good" rating of 300ms. What the data tells us is that the top 2 rankings are consistently below this performance threshold, while results 3-9 tend to perform poorly.

This implies that there are a lot of asset-heavy websites with long loading tasks that delay user interactivity.

Total Blocking Time (TBT) Results

Top 5 average

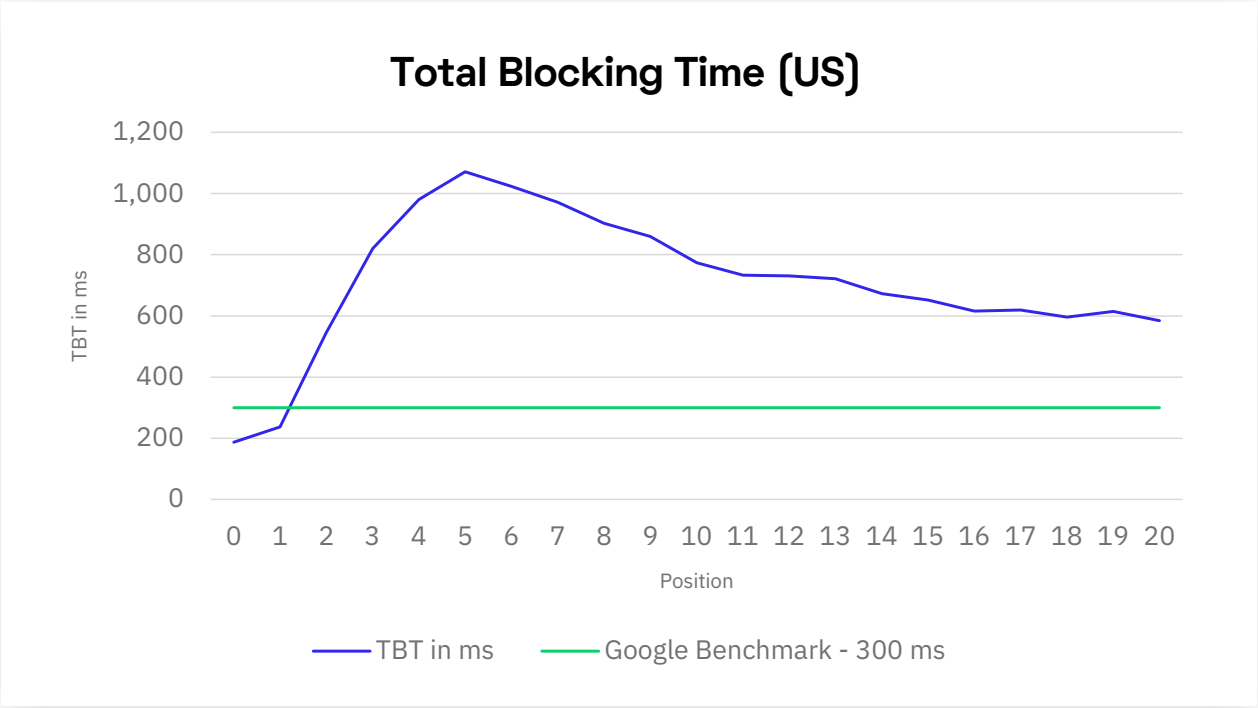
554 ms **6.12** sec

84.6% slower than Google's benchmark of 300 ms.

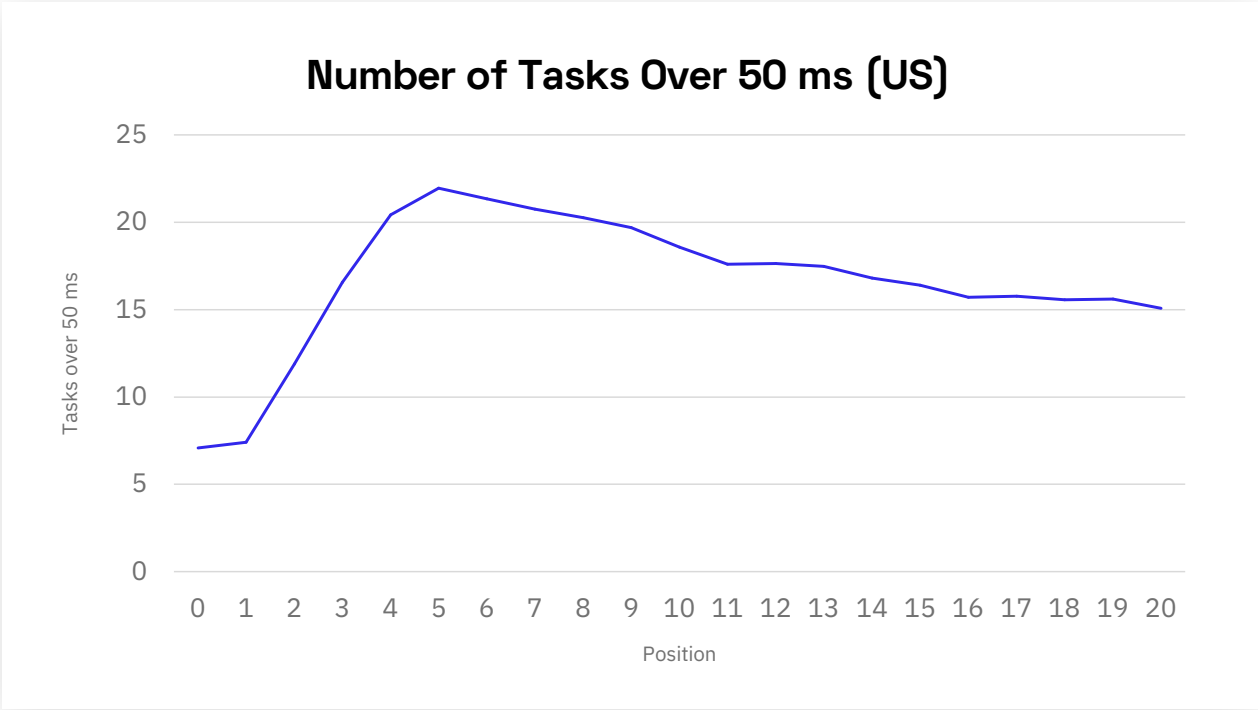
Top 20 average

710 ms **6.27** sec

136.7% slower than Google's benchmark 300 ms.



A quick comparison of the TBT chart with the number of tasks over 50ms confirms this finding. On average, the top 3 ranking positions have much fewer long tasks. Long tasks increase TBT which makes a page less interactive for users.



Worst Case Example: YouTube

The video platform features a lot of pages with a TBT of over 10 seconds. This shows that the website needs to complete a lot of long tasks before the web page is fully interactive. Many video or image-heavy websites struggle with TBT performance.

Best Case Example: Wikipedia

Once again Wikipedia shows that a lightweight approach to website design results in excellent page loading metrics. Wikipedia has a lot of pages with a TBT of 0. It achieves this by not having any long loading tasks over 50ms – plugins, excessive JavaScript or large video files to fetch.

Tips to improve TBT

- Reduce the number of CSS stylesheets that are loaded.
- Only load critical CSS and JavaScript.
- Reduce the impact of third-party code and plugins.
- Keep server request counts low and transfer sizes small.

Cumulative Layout Shift (CLS)

CLS measures the “sum total of all individual layout shift scores for every unexpected layout shift that occurs during the entire lifespan of the page.” – Google[14]. In simple terms, it’s a measure of how much the elements on your page jump about or shift. This shift creates a negative user experience.

Google offers two benchmarks: < 0.1 = good; < 0.25 needs improvement – everything else is poor.

We found that CLS had a strong positive correlation (0.2) with higher rankings.

Nevertheless, only the top position (featured snippet) or position 0, achieved a “good” score across our keyword set. Position 1 was close. All other positions were in the “poor” band of CLS > 0.25.

Cumulative Layout Shift (CLS) Results

Top 5 average

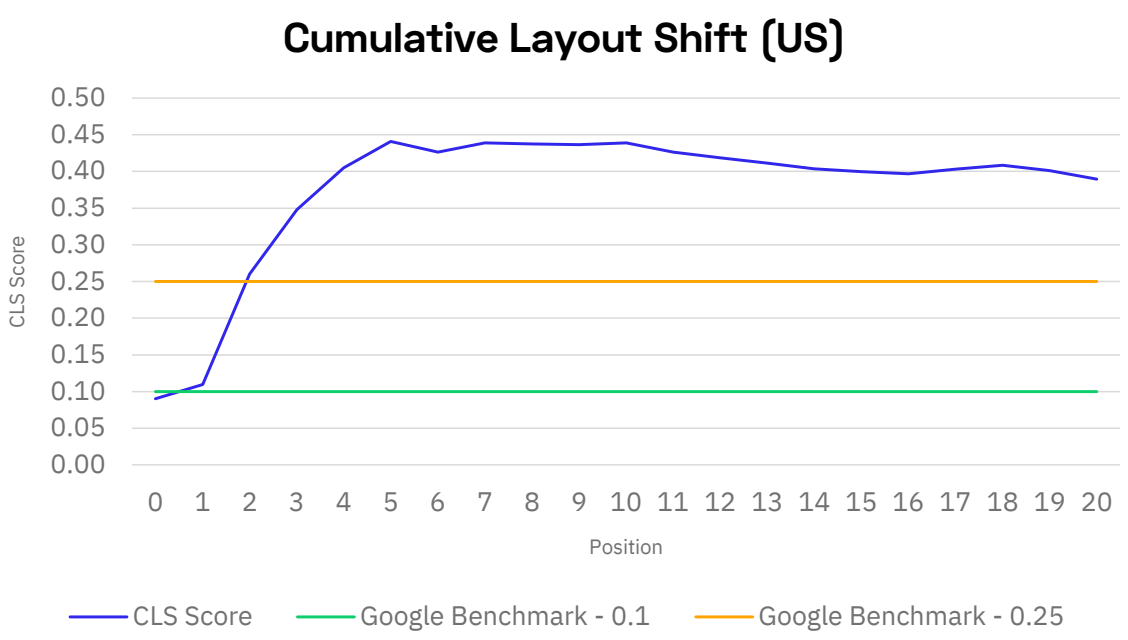
0.24 0.27

142.6% worse than Google's "good" benchmark of 0.1.

Top 20 average

0.38 0.29

275.6% worse than Google's "good" benchmark.



The main causes of layout shifts include media pop-outs such as "subscribe now" boxes, or ads. Websites that do not allow for this dynamic content in their layouts perform poorly in terms of CLS.

Worst Case Example: The Spruce Eats

The recipe website The Spruce Eats for the keyword phrase like "how to roast chestnuts" has visual stability issues caused by ads and pop-ups, resulting in a CLS score of 0.99. As the web page loads, elements jump around as dynamic content is served.

Best Case Example: Wikipedia

Wikipedia strikes again. Many pages have a CLS score of 0! This is because Wikipedia uses a relatively fixed layout for the vast majority of its pages. It also does not run advertisements and can limit the amount of dynamic content served.

Tips to improve CLS

- Understand which elements can shift on your pages and plan your layout to include enough space for them.
- Always include size attributes on your images and video elements, or otherwise reserve the required space with something like CSS aspect ratio boxes.
- Never insert content above existing content, except in response to a user interaction. This ensures any layout shifts that occur are expected.

More Web Vitals

The three Core Web Vitals metrics are a great starting point for analyzing web page performance. But they don't tell the whole story. We now turn our attention to the other Web Vitals metrics.

Time to Interactive (TTI)

TTI measures how long it takes a page to become fully interactive. Effectively, it measures the time from when the first element starts loading (FCP) to the time when there are no long tasks (50ms or longer) preventing the user from interacting with the page.

*"To provide a good user experience, sites should strive to have a **Time to Interactive of less than 5 seconds when tested on average mobile hardware.**"* – Google[15]

All top 20 ranking web pages did not achieve a "good" TTI score improvement. The top 5 average and to 20 average TTI scores were very similar – 5.9 and 6.0 seconds, respectively.

It is interesting to note that the TTI chart is much flatter than that of the previous metrics.

This suggests that a lot of websites have very similar TTI scores. Nevertheless, a good TTI score implies quick loading times which creates a better user experience, so it is worth understanding how to improve it.

Time to Interactive (TTI) Results

Top 5 average

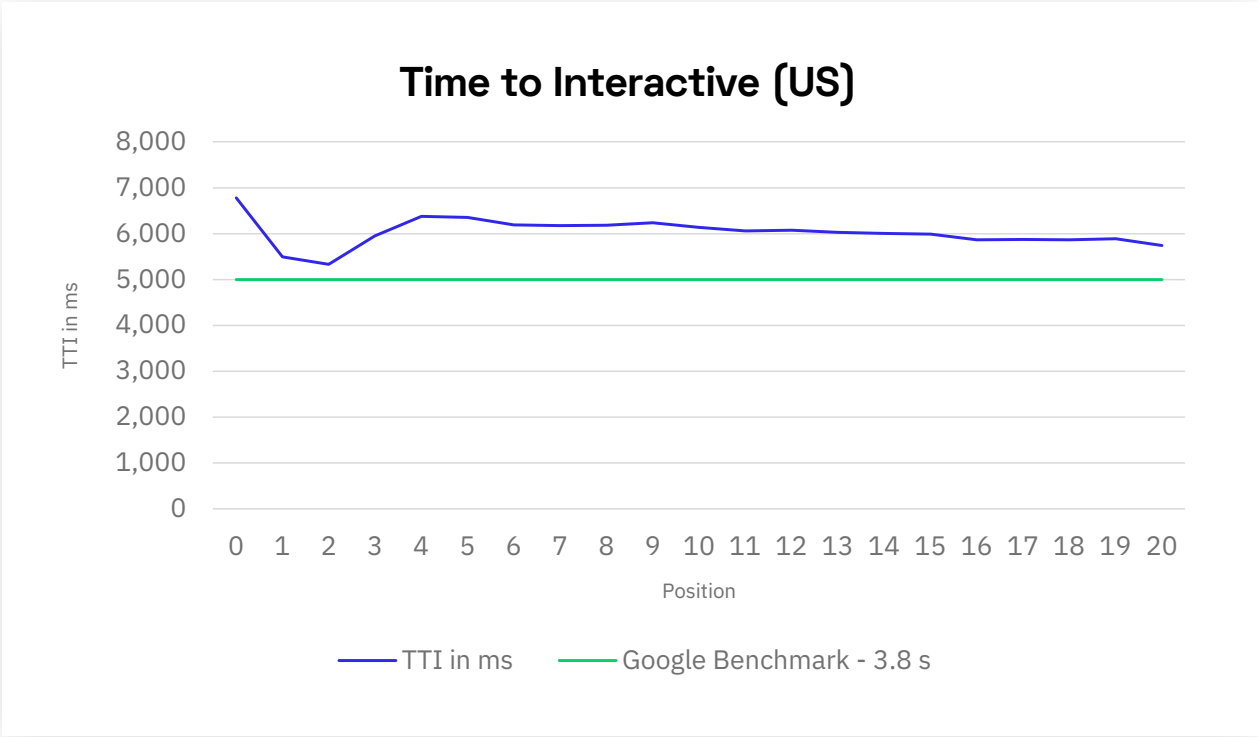
5.9 sec 24.98 sec

19.7% slower than Google's benchmark of 5 seconds

Top 20 average

6.0 sec 25.52 sec

20.6% slower than Google's benchmark of 5 seconds.



Worst Case Example: Bleacher Report

The Bleacher Report sports website features web pages with TTI results of over 20 seconds. The website continually loads in more dynamic elements, such as Tweets and links to other articles.

However, this all happens as soon as a visitor lands on the page, rather than deferring or loading these assets asynchronously. This means that there are lags before being a user can click on elements on the page.

Best Case Example: White House

The official White House website homepage had a TTI of around 0.5 seconds. This means that after this time, the page is fully interactive. It avoids loading heavy resources such as videos, sticking with images and text.

Tips to improve TTI

- Google advises focusing on overall website performance.
- Reduce JavaScript execution time with fewer plugins.
- Optimize images and videos.
- Keep server request counts low and transfer sizes small.

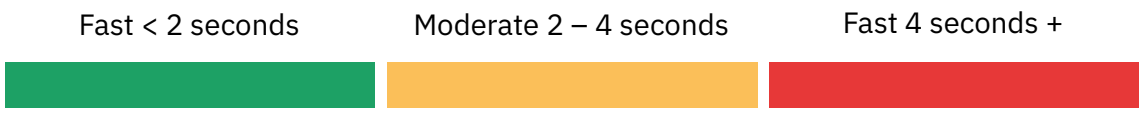
First Contentful Paint (FCP)

FCP measures how long it takes the browser to render the first piece of content after a user navigates to your page.

"Your FCP score is a comparison of your page's FCP time and FCP times for real websites, based on data from the HTTP Archive. For example, sites performing in the ninety-ninth percentile render FCP in about 1.5 seconds. If your website's FCP is 1.5 seconds, your FCP score is 99." - Google[16]

Note that the exact benchmarks for receiving a "good" score can change over time. Currently, to receive a "good" score from Google, websites would need to achieve an FCP of less than 2 seconds.

Looking at the data, all positions are below the 2-second threshold. This is an example of the top 3 outperforming Google's "good" benchmark.



First Contentful Paint (FCP) Results

Top 5 average

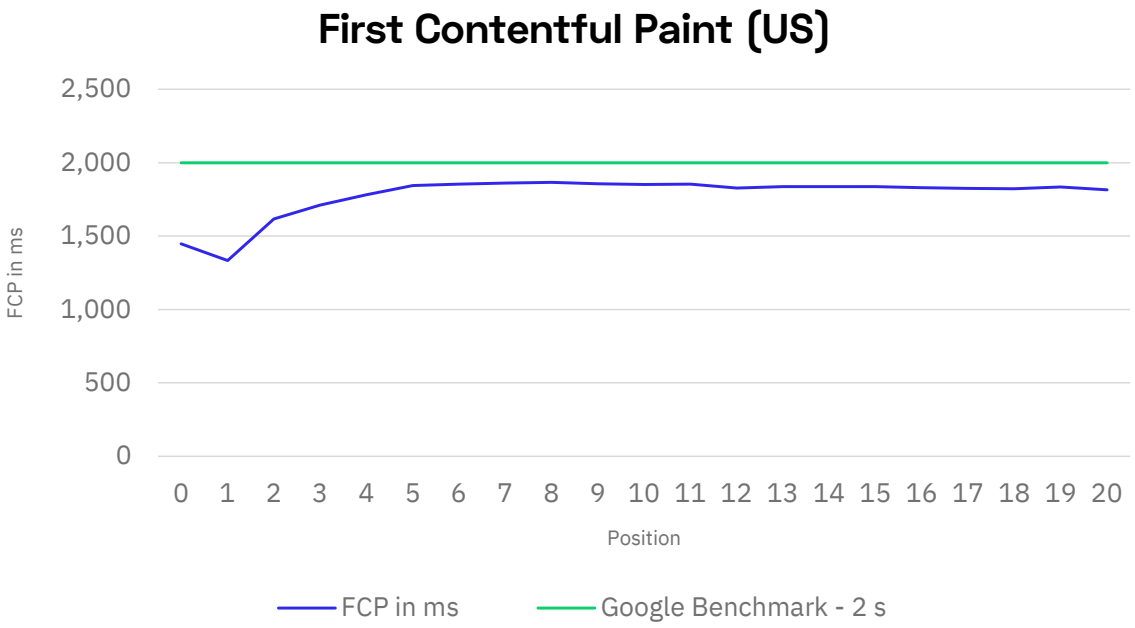
1.58 sec 2.55 sec

21.1% quicker than Google's benchmark of 2 seconds.

Top 20 average

1.78 sec 2.47 sec

11.1% quicker than Google's benchmark of 2 seconds.



Worst Case Example: Khan Academy

The online e-learning platform also performs poorly in terms of FCP. The platform embeds its videos in iframes and does not optimize the loading times of these assets. As a result, the server has to complete this task before it can render the first element.

Once again, a preferred approach would be to load a static video thumbnail or placeholder image and defer the loading of the video asset until the rest of the web page has been rendered.

Best Case Example: Fantastic Fiction

This website for literary fans follows a Wikipedia-esque, lightweight approach, using mainly images and text. Its author bio pages have fast LCP times in the region of 0.4-0.6 seconds. It achieves this by keeping asset sizes small and minimizing the number of requests made before loading the first piece of content.

Tips to improve FCP

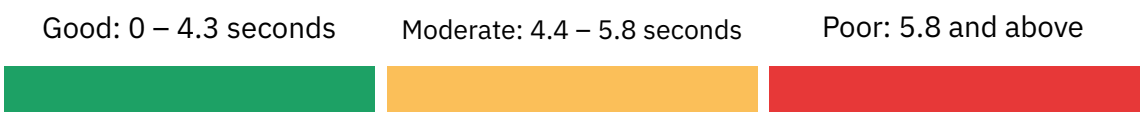
- Eliminate render-blocking resources.
- Remove unused CSS and JavaScript.
- Avoid enormous network payloads by keeping page size small.

Speed Index

Speed Index measures how quickly content is visually displayed during page load. Lighthouse[17] first captures a video of the page loading in the browser and computes the visual progression between frames. Lighthouse then uses the Speedline Node.js module to generate the Speed Index score.

Note that the benchmarks are based on HTTP data and can change over time.

Current Scoring Model



From the data, we can see that all web pages are well below the “good” threshold. The first positions in particular seem to have a much quicker speed index. Even if you score well on this metric, it may not be enough to secure top rankings.

Based on this data, a speed index of around 2 seconds would be a great target to aim for.

Speed Index Results

Top 5 average

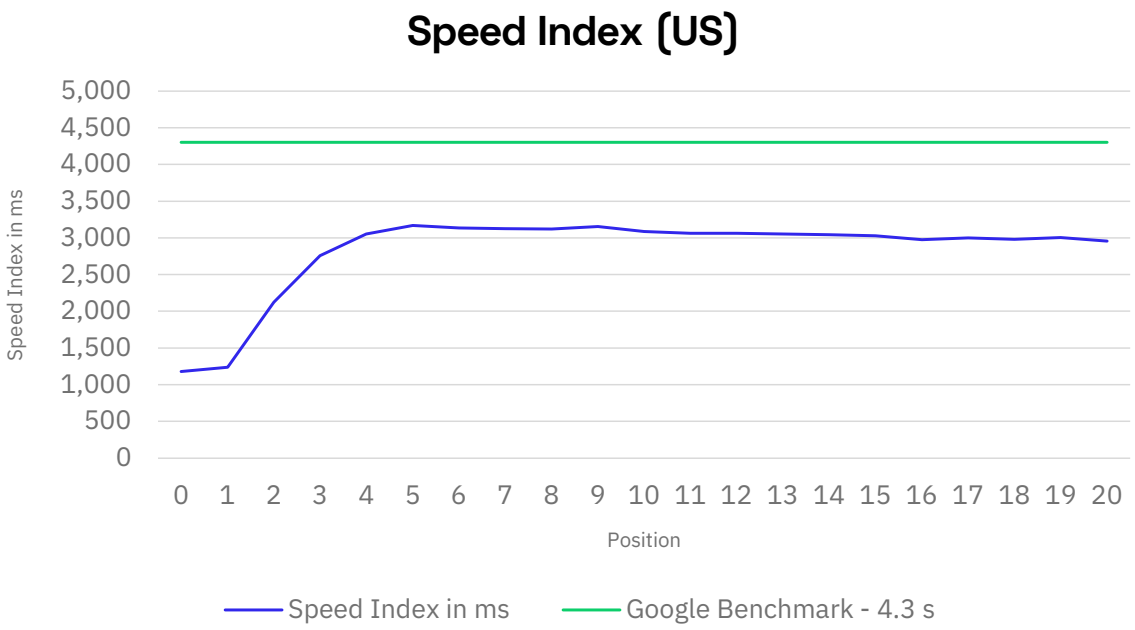
2.01 sec 11.27 sec

51.9% faster than Google's benchmark of 4.3 seconds.

Top 20 average

2.82 sec 11.60 sec

34.3% faster than Google's benchmark of 4.3 seconds.



Worst Case Example: Lonely Planet

The travel website performs poorly across speed and page loading metrics, with many pages around the 10-second mark. The big loss here comes from script evaluation – the browser has to execute an excessive amount of JavaScript before it can render the page. Many of these scripts fetch dynamic assets, so optimizing image loading would result in considerable speed gains.

Best Case Example: Distractify

Distractify is an online media and pop culture publication. With multiple pages achieving a Speed Index of just 300ms, this website manages to strike the balance between speed and user experience while still running ads. It achieves this level of performance by keeping the total size of assets requested very low while reducing scripts that block page rendering.

Tips to improve Speed Index

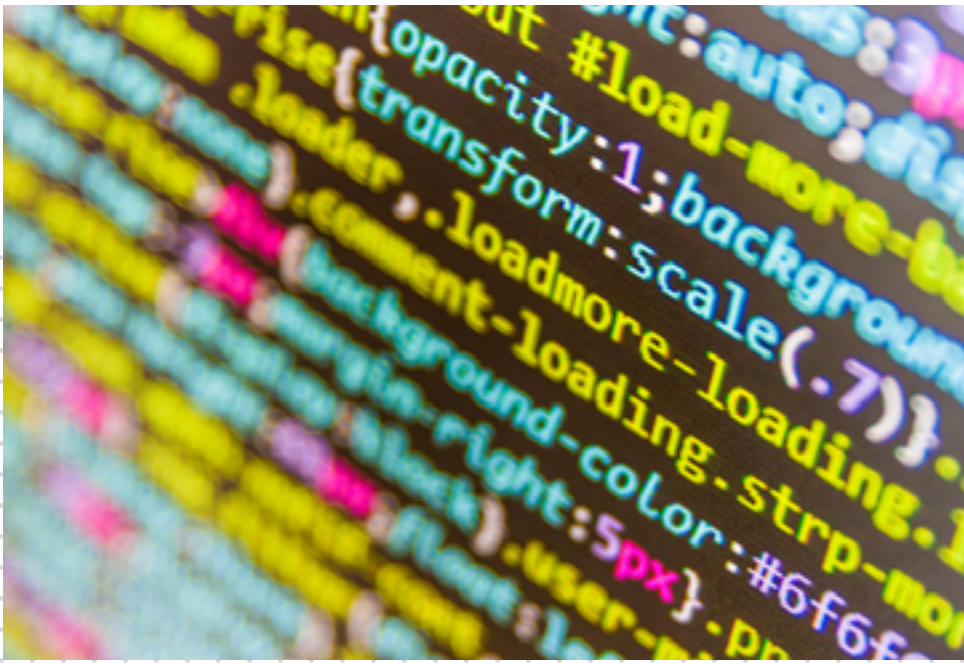
- Anything to improve page load, with a focus on slow JavaScript assets.
- Optimizing images or using an image format like WebP can reduce asset size.
- Eliminate unused JavaScript and CSS.

Web Vitals Metrics vs. Opportunities

While the previous metrics directly impact your Lighthouse or PageSpeed scores, the following are opportunities to improve. A Lighthouse Audit (or other Core Web Vitals reports) shows you where your website can gain performance.

These scores will not directly contribute to the overall score. But they do contribute indirectly.

For example, a website with unused JS and CSS will usually lead to larger file sizes and slower load times.



Unused CSS Rules

Often web pages load CSS stylesheets all at the same time, even if they don't need them for that particular page. A more streamlined approach is to only load what is necessary for each page. The chart below shows the average potential page load savings in milliseconds across the websites ranking in the top 20 positions. On average, websites could save around 100ms in page load time if they optimized their CSS.

Unused CSS Results

Top 5 average

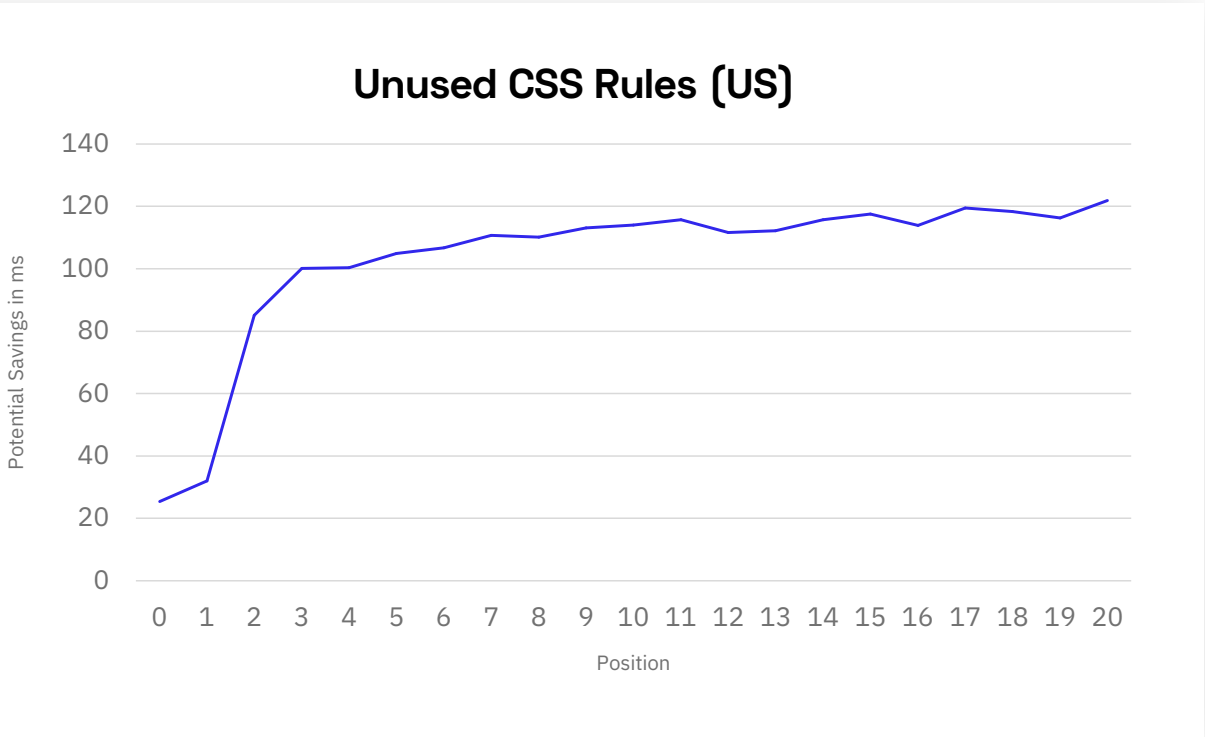
68 ms

481 ms

Top 20 average

103 ms

496 ms



Worst Case Example: BBC News

The BBC news website performed poorly in terms of unused CSS. Many web pages could save 1.5-2 seconds by only loading the CSS stylesheets that are needed for that web page. The BBC website loads different stylesheets for pages even when they are not needed to render the page. This slows the loading time considerably.

Best Case Example: How-To Geek

How-To Geek is a technology tutorial website. Even though it serves dynamic ads and has a substantial amount of media assets, it still how performed very well in terms of unused CSS. How-To Geek's approach is to have a uniform way of styling its pages, but this one size fits all approach works well as most pages do not feature unused CSS rules.

How to reduce unused CSS?

- Use the 'Coverage' tab in Chrome DevTools[18] to identify non-critical CSS.
- When you load or run a page, the information in this tab tells you how much code was used versus how much was loaded.
- Based on this, only load the critical CSS and defer other assets.
- Reduce the number of plugins you use if you use a web builder/CMS like WordPress.

Unused JavaScript

While the potential CSS savings were quite low, the JavaScript load time savings were much higher.

On average the top 20 ranking URLs could save almost one second by optimizing their JavaScript.

High scores occur when a webpage loads JavaScript that is not necessary to display the page. This often results from web templates loading unnecessary resources.

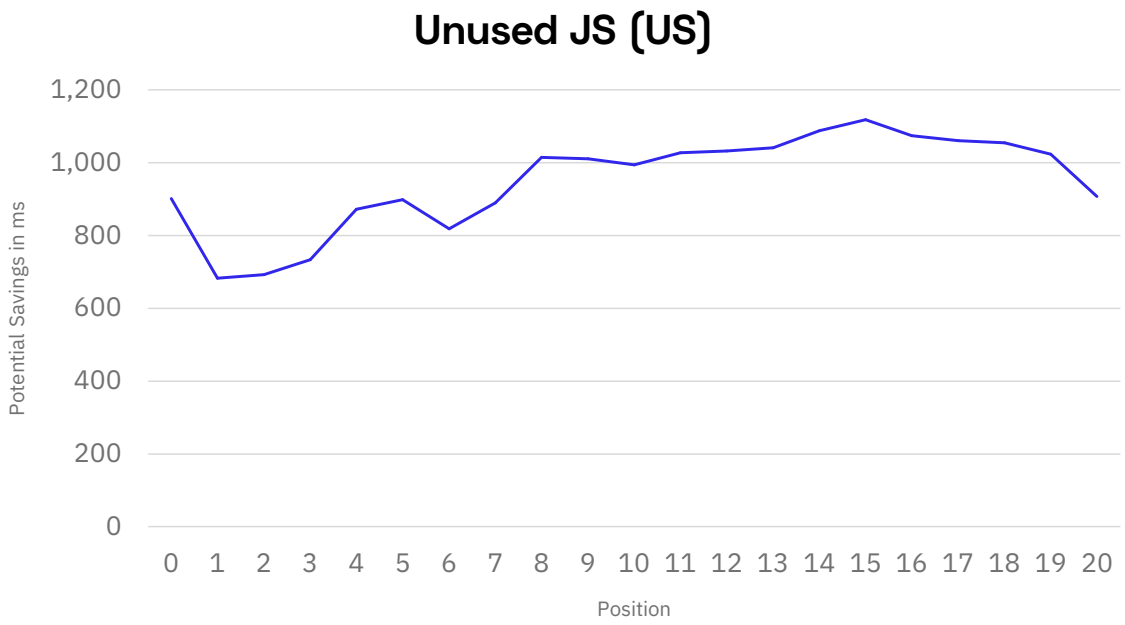
Unused JavaScript Results

Top 5 average

776 ms **3.70** sec

Top 20 average

949 ms **4.13** sec



Worst Case Example: Bleacher Report

The Bleacher Report uses JavaScript to load dynamic content. The problem is that often these scripts are not needed to render the page. One example is loading a script that can insert Tweets, even if there are no Tweets featured in that article.

The Bleacher Report is a classic example of code bloat – removing unused JavaScript would result in massive performance gains.

Best Case Example: IMDB

IMDB does not load anything it doesn't need. Similarly to Wikipedia it has one primary layout for its pages and keeps its JavaScript to a minimum.

How to reduce unused JavaScript?

- Use the Coverage tab in Chrome DevTools[19] to identify non-critical JavaScript. When you load or run a page, the tab tells you how much code was used, versus how much was loaded.
- Based on these results, inline critical JavaScript and defer the rest.
- Reduce the number of plugins you use.

Web Vitals Image Metrics

We measured three Web Vitals image metrics, all of which correlated positively with higher rankings. When we compare them we see that, on average, using WebP images offers the most potential savings. (WebP is an image format developed by Google that reduces image size by around 25%.)

One reason why WebP potential savings are higher could be because many websites have not yet adopted the WebP format.

On average, the top 20 ranking URLs websites could save 286ms in load time by using WebP images. Using responsive images would save the top 20 ranking URLs an average of 196ms and optimizing images an average of 96ms.

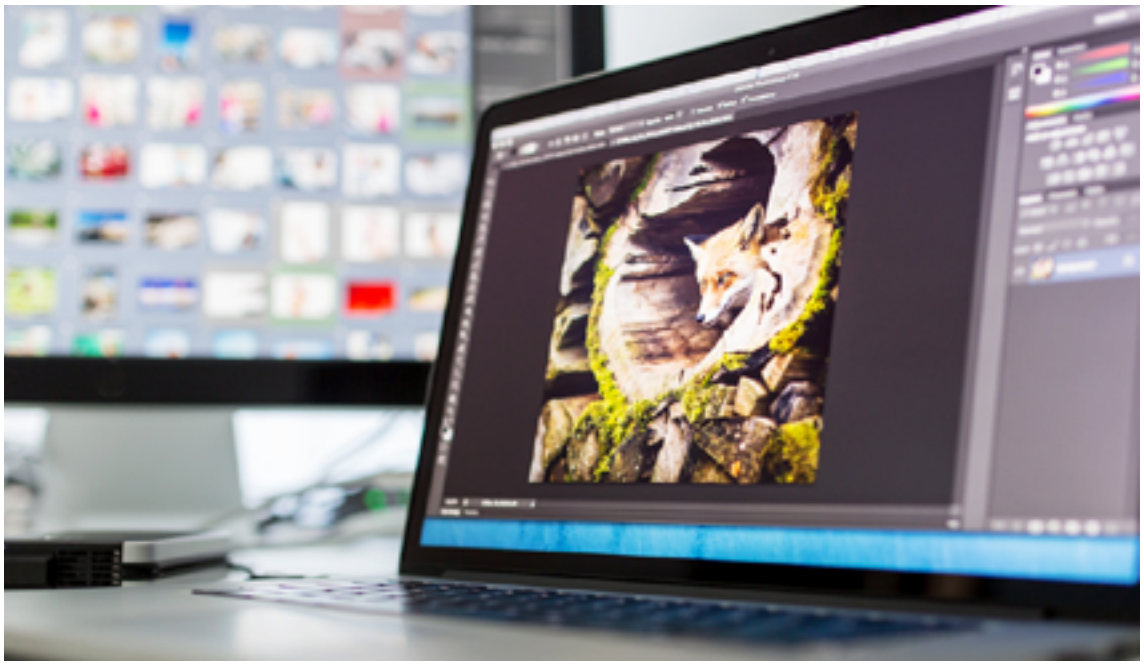


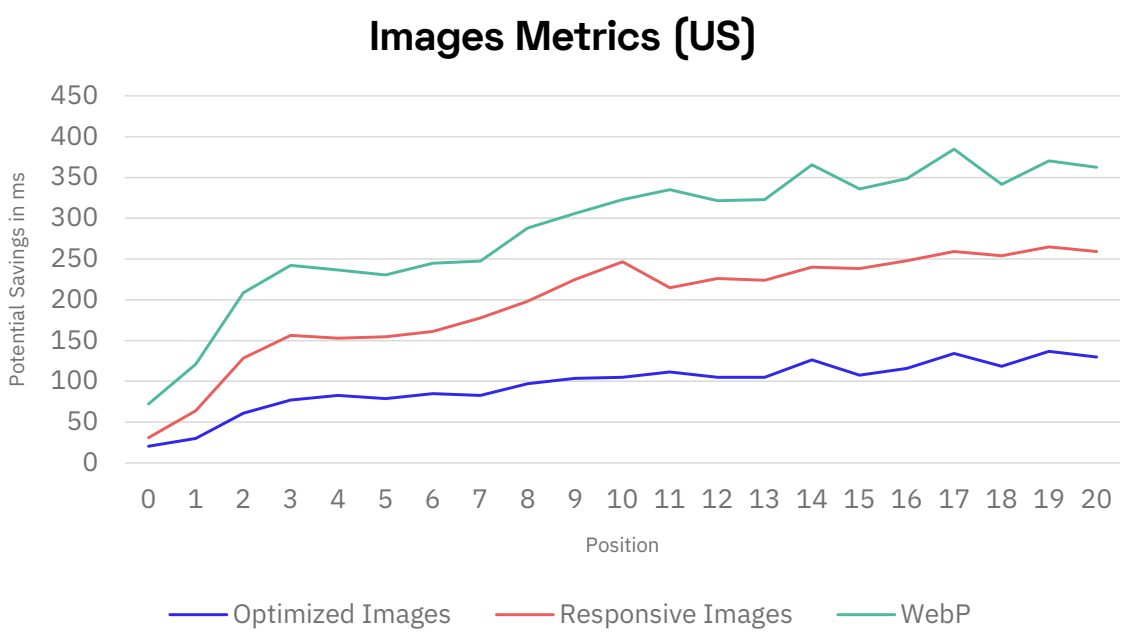
Image Metric Results

Top 5 average

Optimized Images	54 ms	657 ms
Responsive Images	106 ms	793 ms
WebP Images	176 ms	1.93 sec

Top 20 average

Optimized Images	96 ms	665 ms
Responsive Images	196 ms	795 ms
WebP Images	286 ms	1.85 sec



Worst Case Example: NBA

The NBA website performs poorly across the image metrics we looked at. The website is image-heavy but does not optimize image size for mobile users. In some cases, reducing image size would result in page load gains of around 20 seconds. One way to do this is to convert JPG images to next-gen image

formats such as WebP. Also, it is important to ensure that the correct image size is defined.

Best Case Example: Poetry Foundation

The Poetry Foundation is a great example multimedia content page that scores well in all three image metrics. By using the WebP image format, it keeps image size low but quality high. It employs responsive design and optimizes image size for mobile devices. The results is a quick loading experience which is not very common for publications in this category.

How to use WebP images?

- Google offers a converter[20] that transforms standard formats into WebP images.
- Other next-gen images such as JPEG 2000 and JPEG XR can also reduce image size.

DOM Size

DOM size measures the number of DOM elements on your web page. The more elements, the more complex the DOM tree and typically the slower the page is to load. Elements include images, videos, text blocks and most other HTML tags.

Lighthouse flags pages with DOM trees that:

- Have more than 1,500 nodes total.
- Have a depth greater than 32 nodes.
- Have a parent node with more than 60 child nodes.

DOM Size Results

Top 5 average

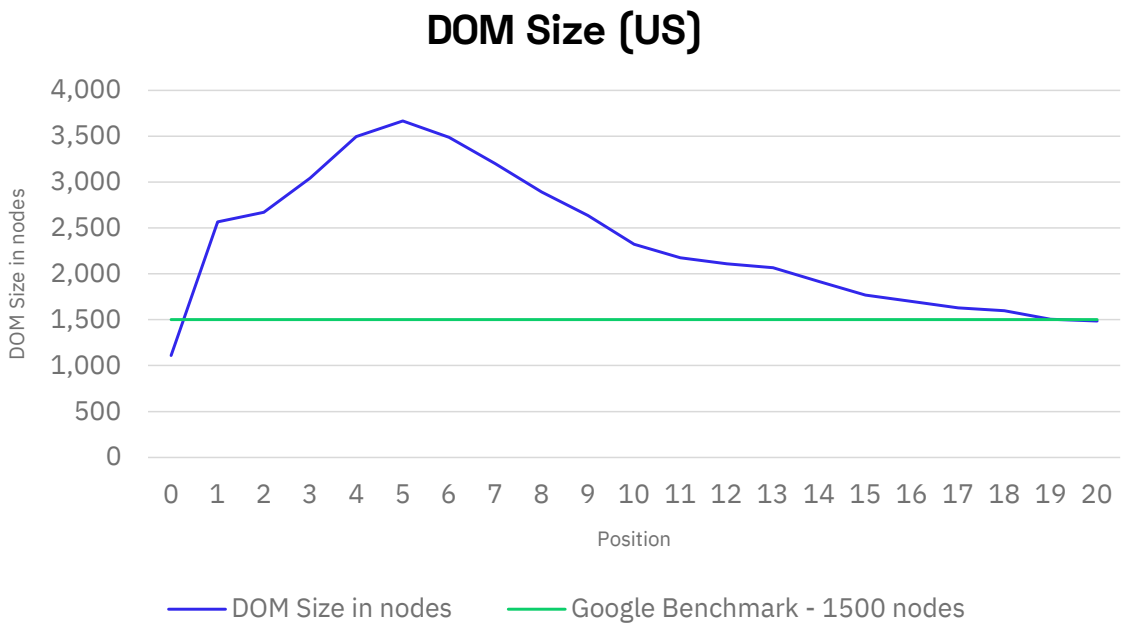
2577 nodes **1284** nodes

71.8% larger than Google's benchmark of 1500 nodes.

Top 20 average

2355 nodes **1228** nodes

55.7% larger than Google's benchmark of 1500 nodes.



Worst Case: NHL

The NHL homepage has over 12,000 DOM elements, well above the recommended limit of 1500. For users, this overly complex webpage results in a slow loading experience. There is an excessive amount of media assets including videos and images.

Best Case: PayPal

PayPal's homepage has less than 300 DOM elements, well below the top 20 average of 2355. PayPal uses a simplistic approach to its web design and avoids loading unnecessary media assets.

How to improve DOM size?

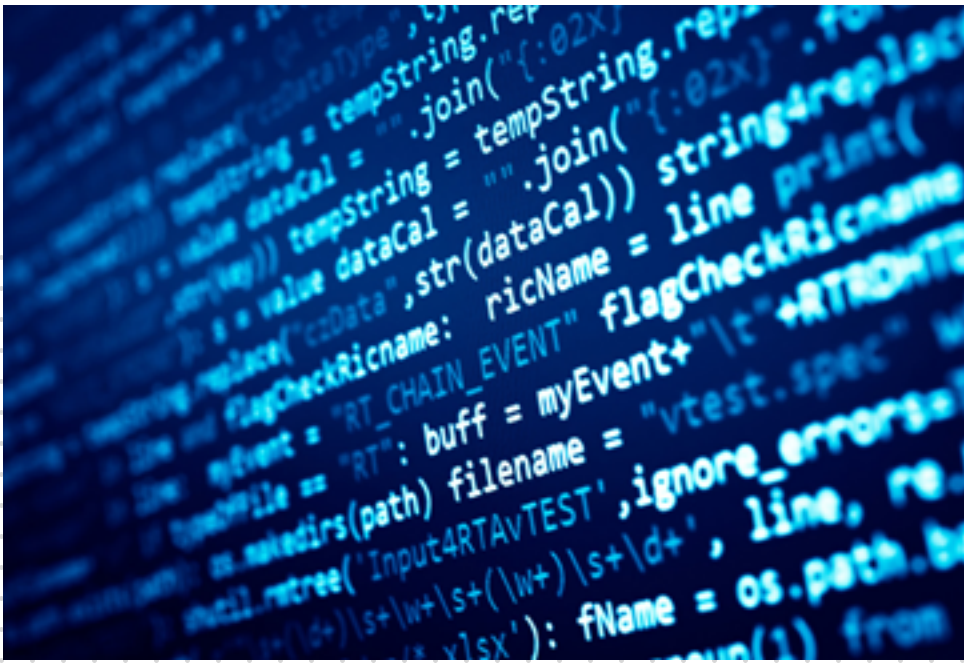
- Reduce unused JS and CSS code.
- Reduce the number of plugins as these can increase DOM complexity.

Render Blocking Resources

Render blocking resources are CSS and JavaScript files that are loaded before the rest of the page. Often these resources are not required to display the first paint of the page. The chart below shows the average savings websites could make by deferring these assets to load after the first paint.

On average, websites analyzed in this study could save over 0.85 seconds by deferring non-critical JS and CSS.

Once again, we notice the peak from positions 3-9. This suggests that, as with other metrics, there are websites with a lot of render-blocking resources that still rank highly.



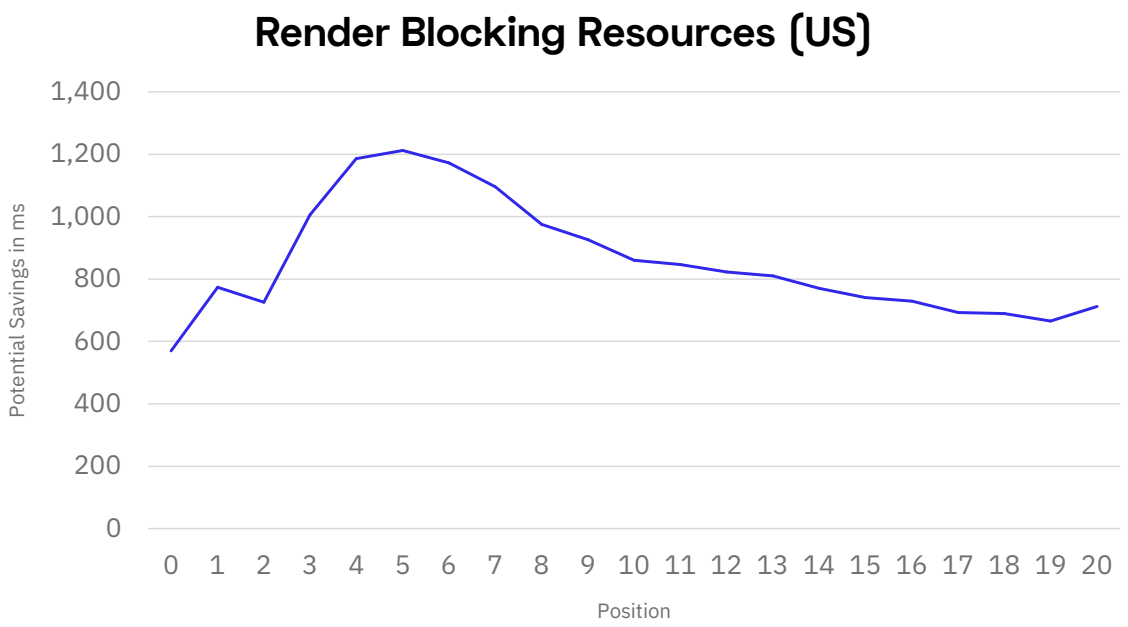
Render Blocking Resources Results

Top 5 average

852 ms 1.38 sec

Top 20 average

856 ms 1.37 sec



Worst Case: Lamborghini

Luxury car manufacturer Lamborghini could save around 2.8 seconds in page load time by eliminating render-blocking resources. The main issue is that the website loads different CSS stylesheets for each individual part of the page. It would be much better to inline the critical CSS rather than load it from external resources.

Best Case: Chicago Tribune

While many online magazines and newspapers struggle with slow loading times, the Chicago Tribune eliminates almost all render-blocking resources. This makes the page loading experience comparatively quick, especially when compared with most publications in this category.

How to improve render-blocking resources?

- Inline critical CSS and JS.
- Defer non-critical CSS and JS.

Total Byte Weight

Total Byte Weight measures the total size of all resources requested by your page. Google recommends aiming for a total byte size below 1,600 KiB.

This target is based on “the amount of data that can be theoretically downloaded on a 3G connection while still achieving a Time to Interactive of 10 seconds or less[21].”

Lighthouse flags pages whose total network requests exceed 5,000 KB.

Looking at the data, the top 5 ranking URLs have an average Total Byte Weight that is 32% lower than the top 20. Websites with large payloads that still rank highly, such as YouTube, have quite a strong influence on this metric as we will discuss in the next section.

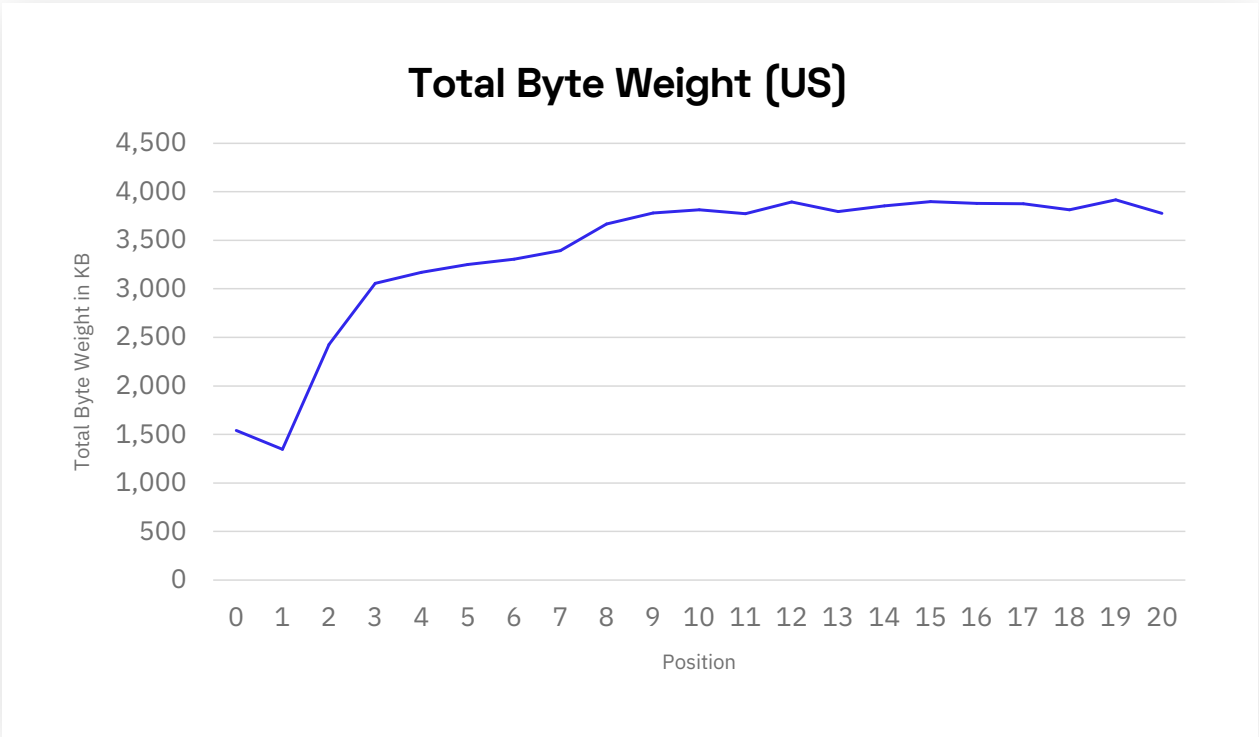
Total Byte Weight Results

Top 5 average

2309 KB **3483** KB

Top 20 average

3392 KB **3774** KB



Worst Case Example: CBS Sports

The sports website homepage is an extreme example of excessive total byte size: its homepage is around 42MB –mainly due to loading excessive amounts of video assets.

Google recommends keeping the total byte size to around 1.6MB for optimal performance. Instead of loading all media assets, a better technique is to load a preview – in the case of videos, a static image; in the case of blog posts, an excerpt. This keeps the byte size to a minimum.

Best Case Example: Oberlo

Oberlo is an eCommerce company owned by Shopify. It manages to keep the size of all assets needed to render the homepage to around 740KB. This is a great example of how to use a homepage to only load selected media items, not everything at once. Also, static images are used as placeholders for videos. Each video is hosted on a separate page.

How to reduce Total Byte Weight?

- Optimize images and consider using next-gen image formats such as WebP, JPEG 2000 and JPEG XR.
- Reduce the number of plugins used.
- Eliminate unnecessary CSS and JavaScript.

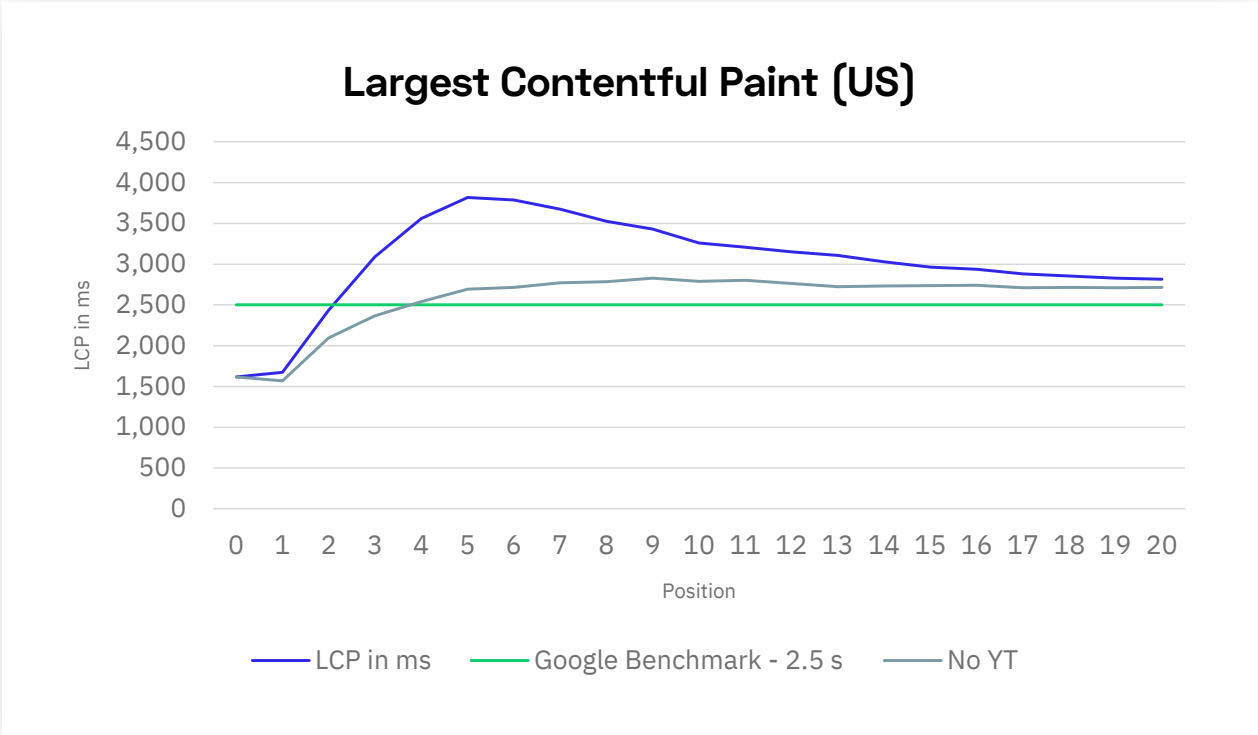
The Influence of YouTube

Many of the Web Vitals metrics exhibit a peak from around positions 3-9. It seems that there are a large number of URLs that perform comparatively poorly in terms of Core Web Vitals but still rank highly. YouTube is an example of an asset-heavy website with relatively slow loading times. Nevertheless, it's a highly popular platform meaning that many user signals will be positive.

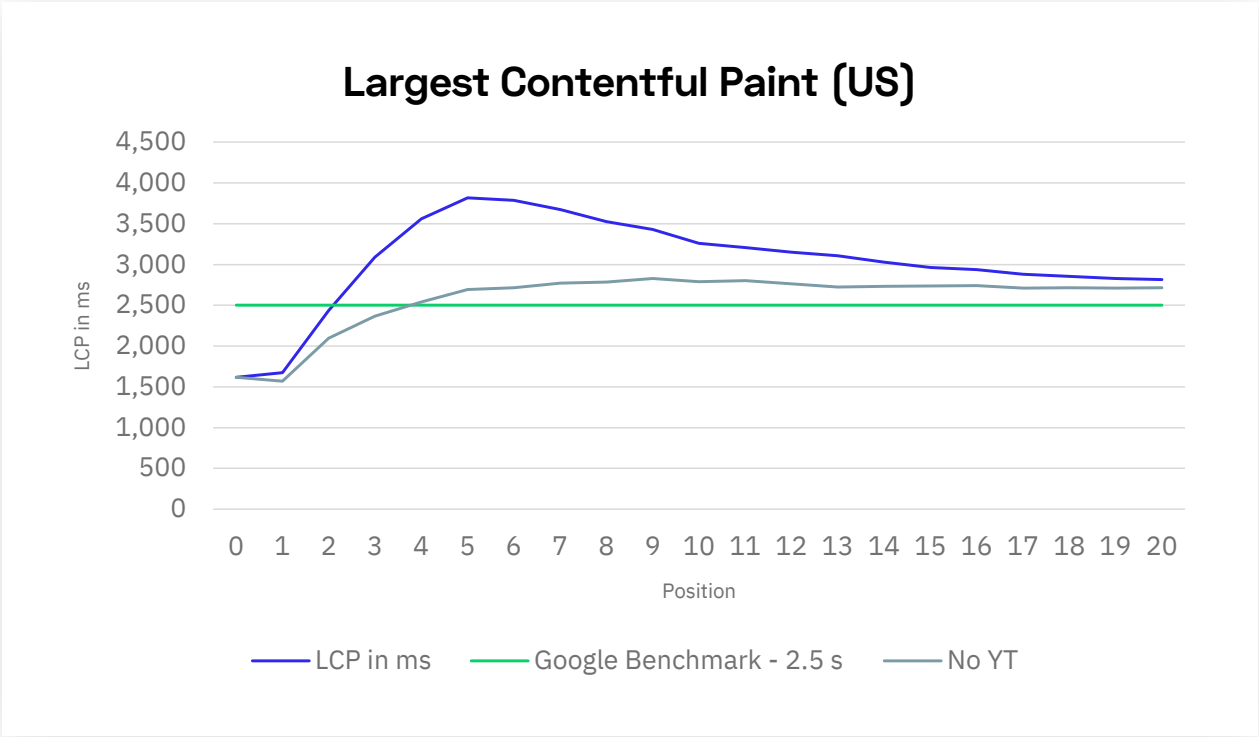
This leads us to the interesting question: **how does a Google-owned entity like YouTube perform for its own Core Web Vitals benchmarks?**

Let's start by comparing the three Core Web Vitals:

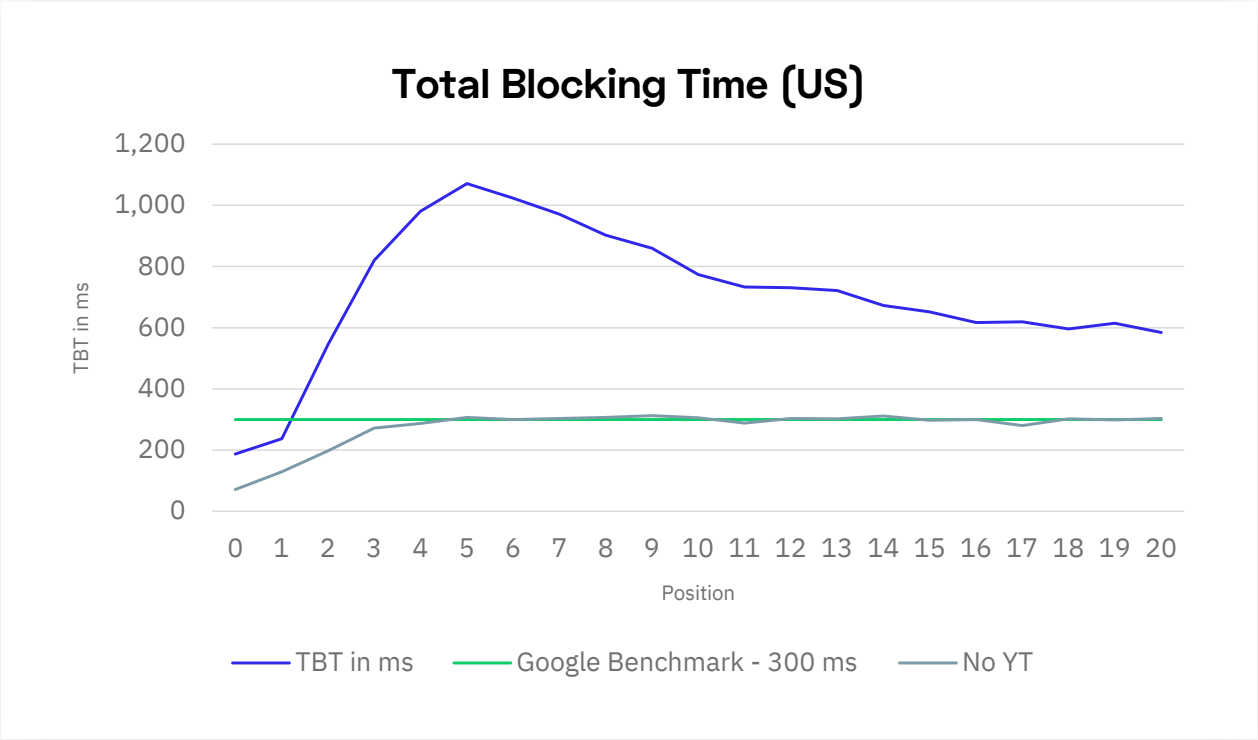
Looking at Largest Contentful Paint first, we can see that filtering out YouTube flattens the peak considerably. The top 20 ranking URLs average LCP drops from 3.0 seconds to around 2.58, just above Google's benchmark. The top 5 average LCP also drops from 2.48 seconds to just 2.04.



However, this is not always the case. Looking at the chart below, we can clearly see that **YouTube has almost no effect on CLS scores**. This suggests that while slow to load, YouTube is visually just as stable as other websites.

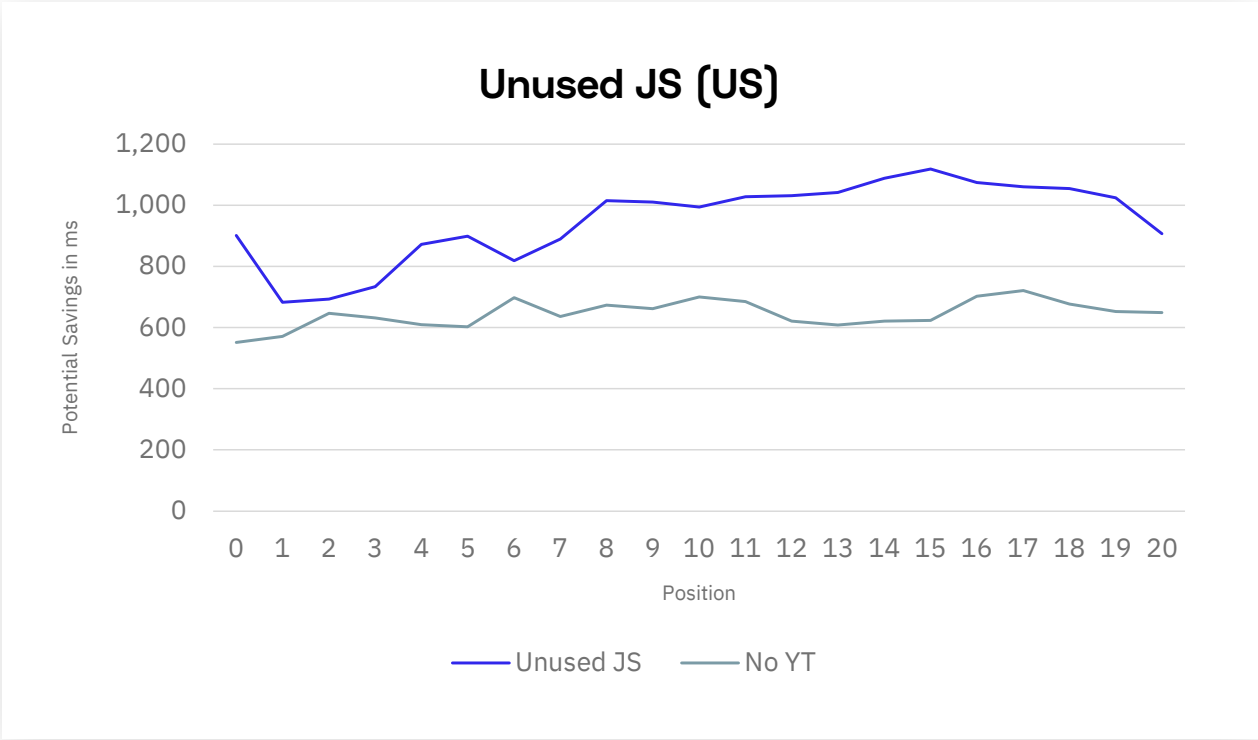


Total Blocking Time (as a proxy for FID) shows a striking difference when YouTube is filtered out. The influence is so great that when YouTube is removed, the average TBT across the top 20 drops from 710ms to 275ms. This means that once YouTube is removed from the top 20 rankings, the average TBT is below Google's "good" threshold of 300ms.

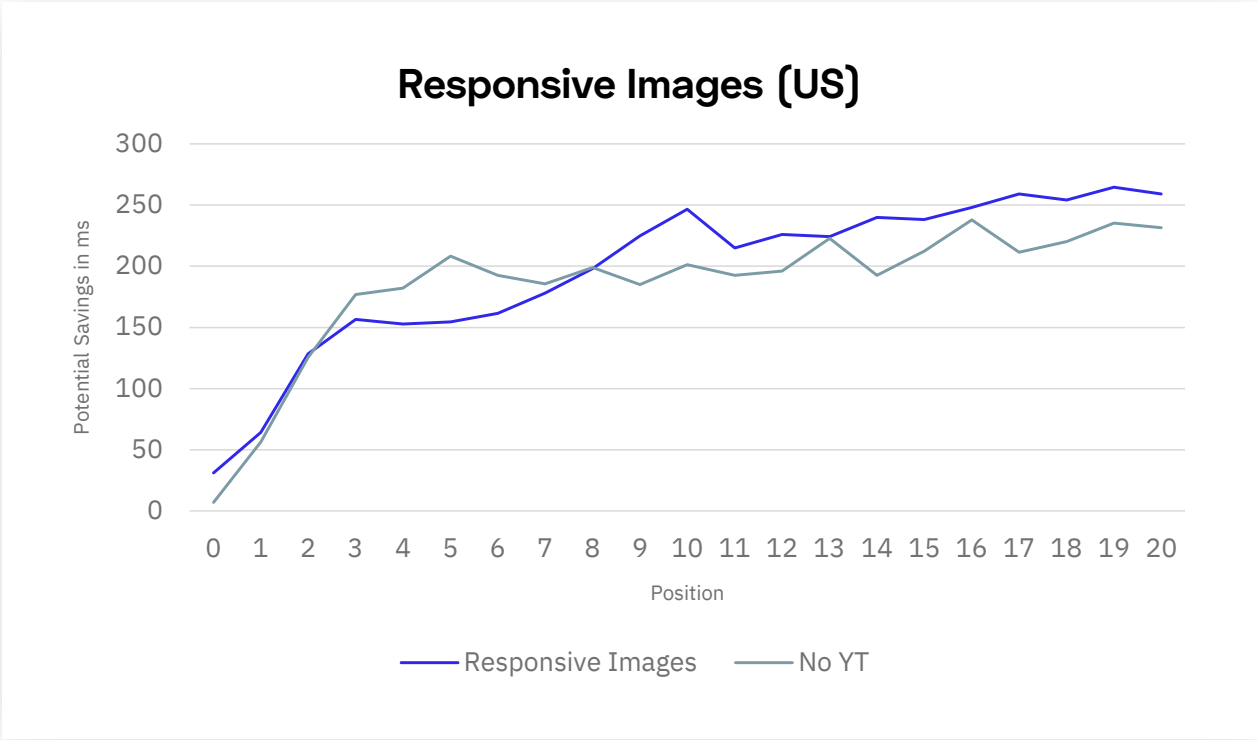


An interesting case is unused JavaScript. The top 20 ranking URLs average potential savings drops 949ms to 645ms when YouTube is removed. This means that YouTube has a lot of URLs that have a significant amount of unused JavaScript.

This is somewhat surprising. While we might expect YouTube to have large asset sizes due to the sheer volume of video content, we would expect a Google-owned website to attempt to cancel this out in other areas, including removing unnecessary JavaScript.



As we would expect from a large video platform, YouTube has little to no effect on the image metrics. YouTube's images and videos seem to at least as optimized as the average website in the top 20.



What does this mean for non-YouTube websites?

In general, YouTube performs poorly across metrics that are related to resource size, loading time or interactivity. On paper, we would expect websites like these to offer a poor user experience, particularly on mobile devices. Nevertheless, websites like YouTube overcome Google's own benchmarks with positive user signals resulting from their overwhelming popularity.

However, most websites don't have the luxury of excellent user signals through extreme brand recognition. Even when YouTube is filtered out, the top 5 ranking websites tend to have a Core Web Vitals performance advantage over the top 20.

The reality is that a website competing with YouTube to rank for video content would have to score significantly better in Core Web Vitals to stand a chance of gaining a higher ranking.

Outlook for Web Developers & Businesses

Are Core Web Vitals important?

Based on our analysis, the data suggests that the highest-ranking websites tend to have a performance advantage in terms of Core Web Vitals scores. Even though Google has not yet integrated Core Web Vitals into the core algorithm, websites that perform well in these metrics tend to offer a good user experience.

But there are exceptions. The findings when filtering out major websites like YouTube show that Google is prepared to "ignore" poor user experience metrics, as long as enough users still choose to visit those websites.

In the case of YouTube, the website performed relatively poorly across almost all loading and interactivity metrics. This leads to the interesting case that a Google-owned entity may not pass most of the Core Web Vitals tests itself.

What does this mean for other websites?

The search rankings landscape is complex. While YouTube seems to be able to overcome poor performance metrics by the sheer volume of positive user signals, this would be unrealistic for the average website.

What this means is that websites should aim to improve their Web Vitals scores as much as possible to give them the best possible chance of ranking highly.

Use Web Vitals as Performance Benchmarks

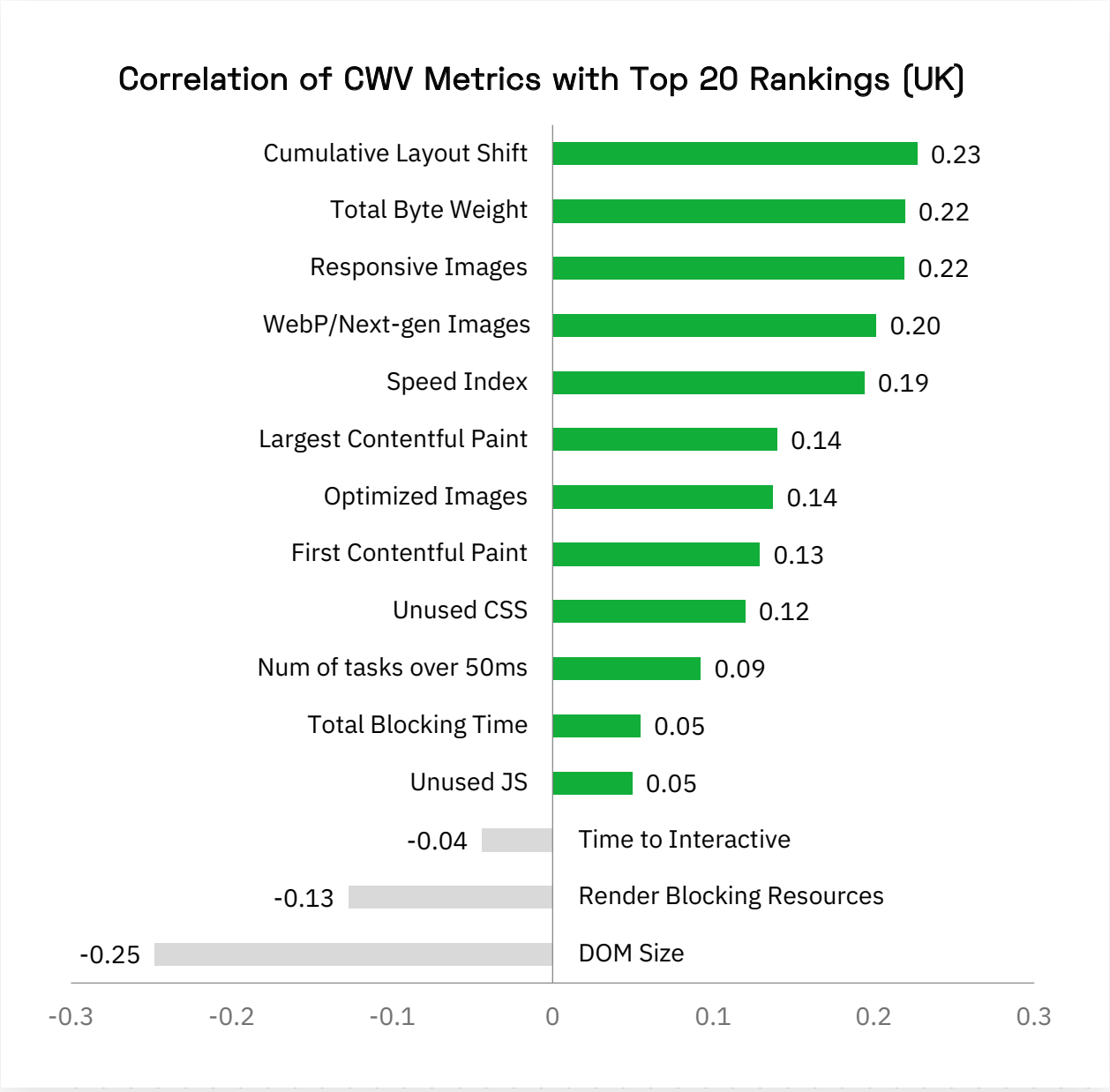
Understanding metrics like Web Vitals can help you ensure a high-quality user experience. Google's "good" ratings are a great place to start assessing your website in terms of loading time, interactivity, and visual stability. The average scores of the top 5 positions outlined in this study give a good indication of how most websites are performing.

Objective Quality Assurance

By understanding these metrics, you can build performance benchmarks into the web design process. Using Core Web Vitals, you can assess at a glance whether your website offers a good user experience or not. They are a great diagnostic tool for identifying where performance gains can be found, from optimizing images to eliminating unused JS or CSS code. This feedback can help guide the web design process in a user-centric way.

Appendix – UK Data

We analyzed the top 20 ranking pages for the UK across a set of carefully chosen keywords for our 15 metrics. Below is the correlation bar chart, showing the correlation coefficients of each metric.



Largest Contentful Paint (LCP) Results

Top 5 average

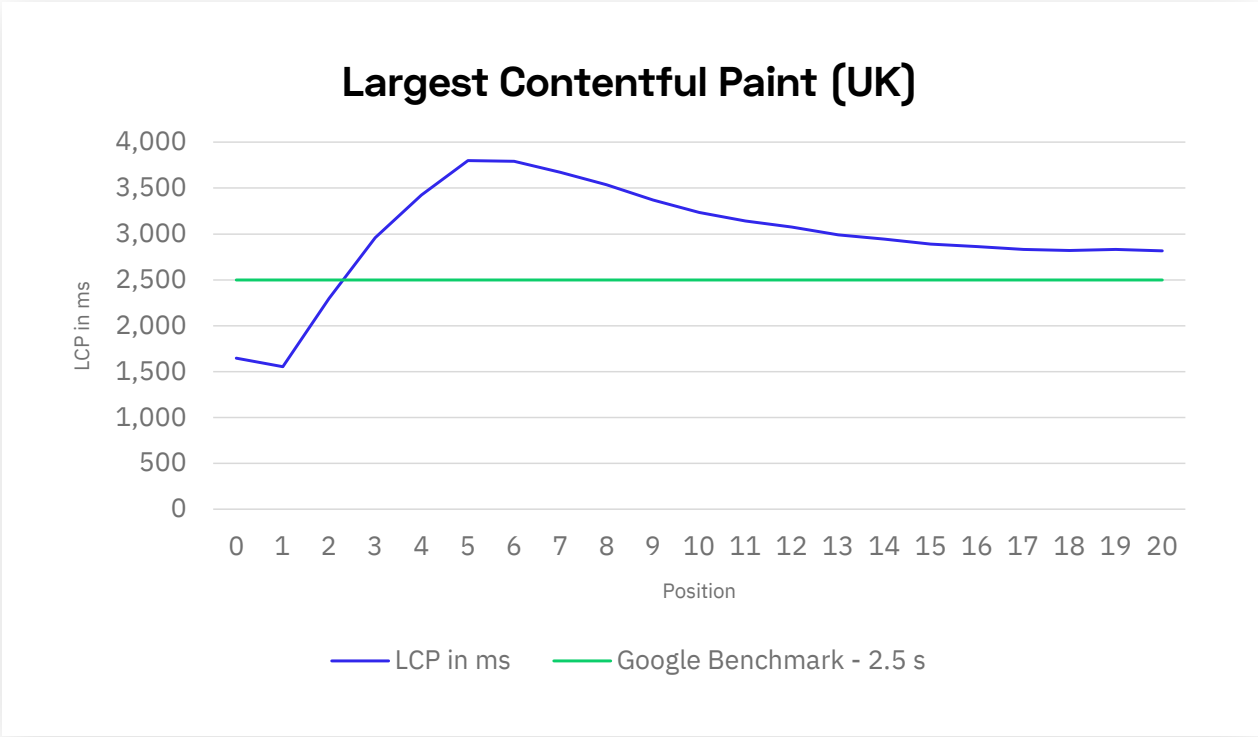
2.38 sec 3.00 sec

4.9% faster than Google's benchmark of 2.5 seconds.

Top 20 average

2.98 sec 3.00 sec

19.0% slower than Google's benchmark.



Total Blocking Time (TBT) Results

Top 5 average

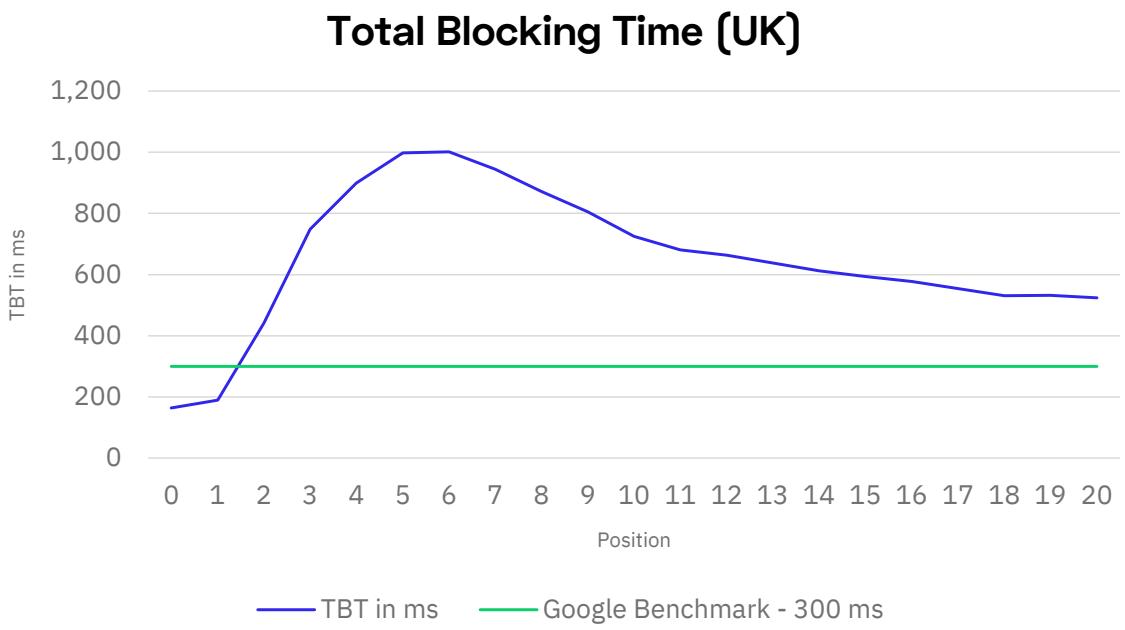
489 ms **5.63** sec

62.9% slower than Google's benchmark of 300 ms.

Top 20 average

652 ms **5.89** sec

117.4% slower than Google's benchmark 300 ms.



Cumulative Layout Shift (CLS) Results

Top 5 average

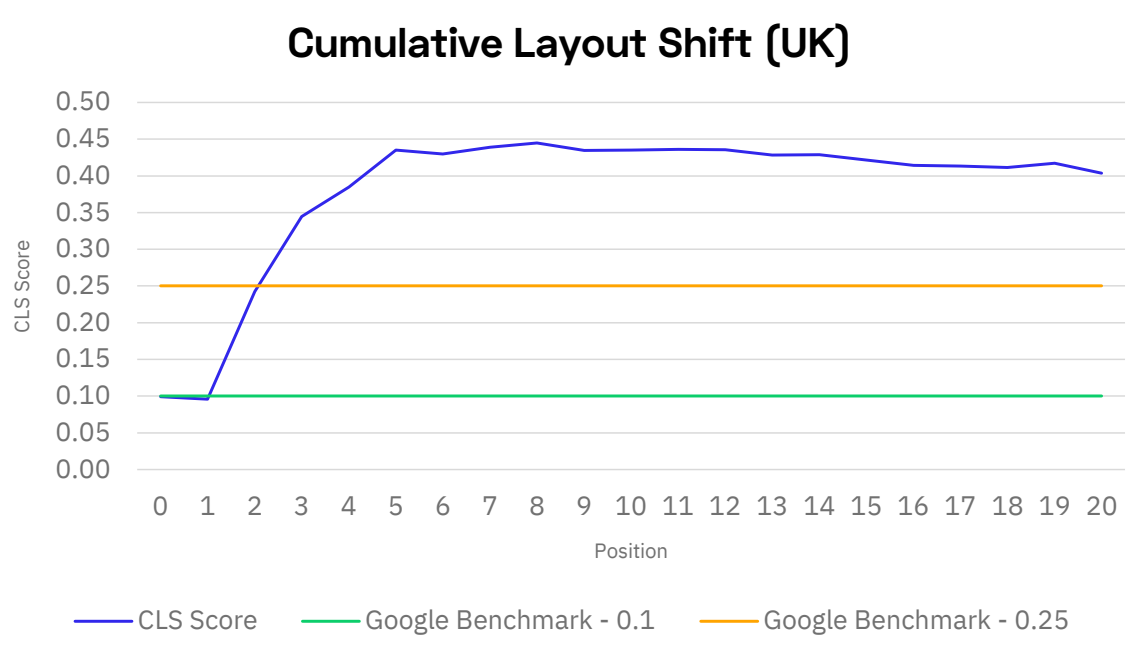
0.23 0.29

133.3% worse than Google's "good" benchmark of 0.1.

Top 20 average

0.38 0.30

280.7% worse than Google's "good" benchmark.



First Contentful Paint (FCP) Results

Top 5 average

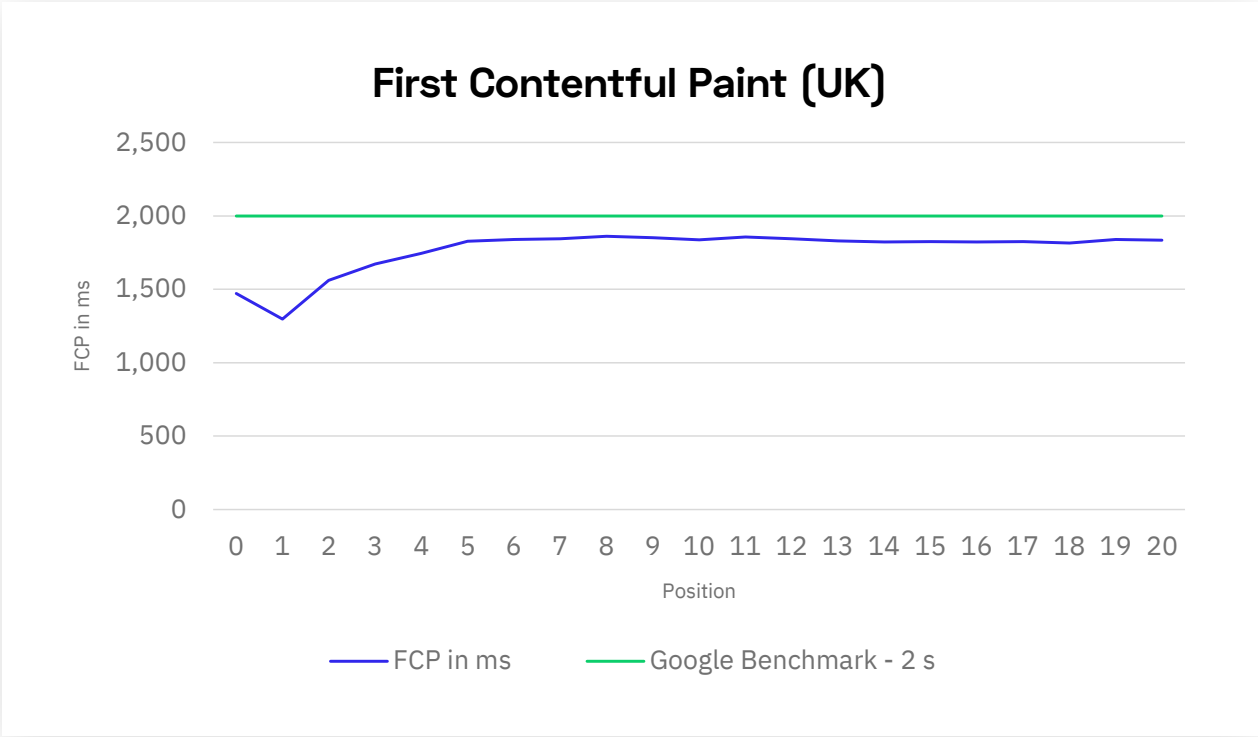
1.55 sec 2.39 sec

22.5% better than Google's benchmark of 2 seconds.

Top 20 average

1.77 sec 2.34 sec

11.6% better than Google's benchmark of 2 seconds.



Time to Interactive (TTI) Results

Top 5 average

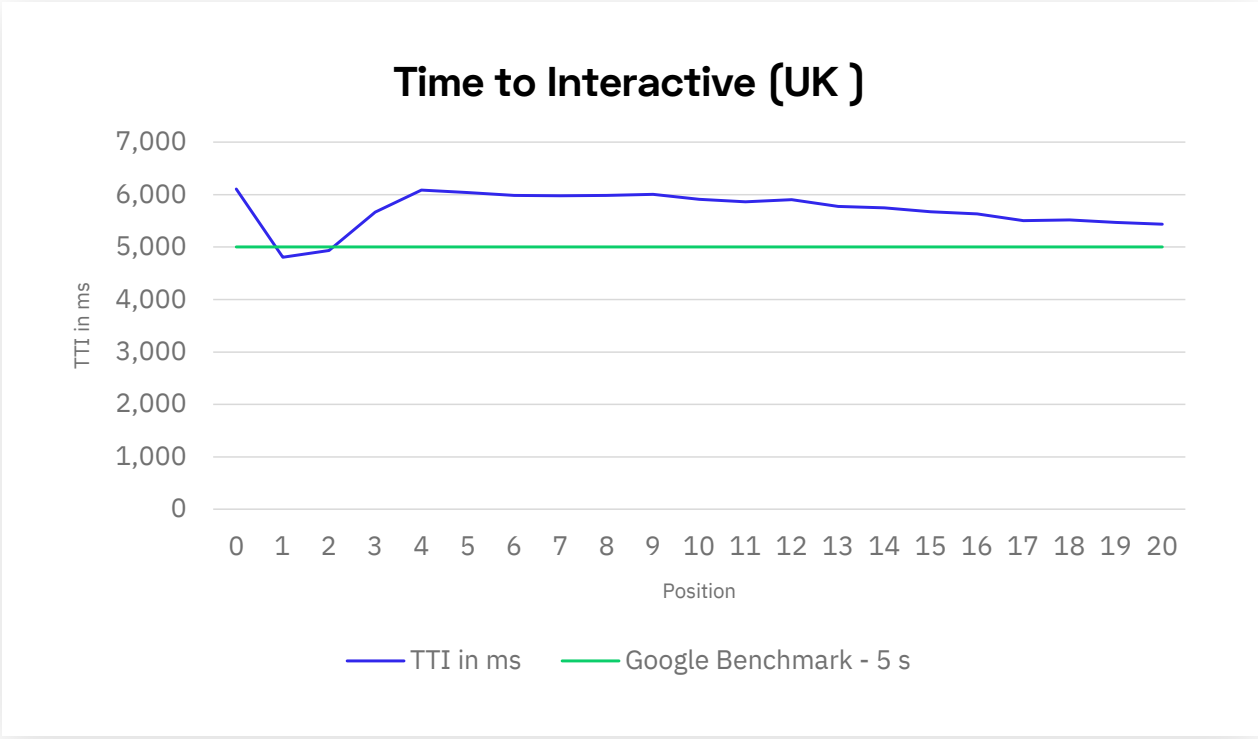
5.5 sec 22.70 sec

10.4% slower than Google's benchmark of 5 seconds

Top 20 average

5.7 sec 24.0 sec

14.3% slower than Google's benchmark.



Speed Index Results

Top 5 average

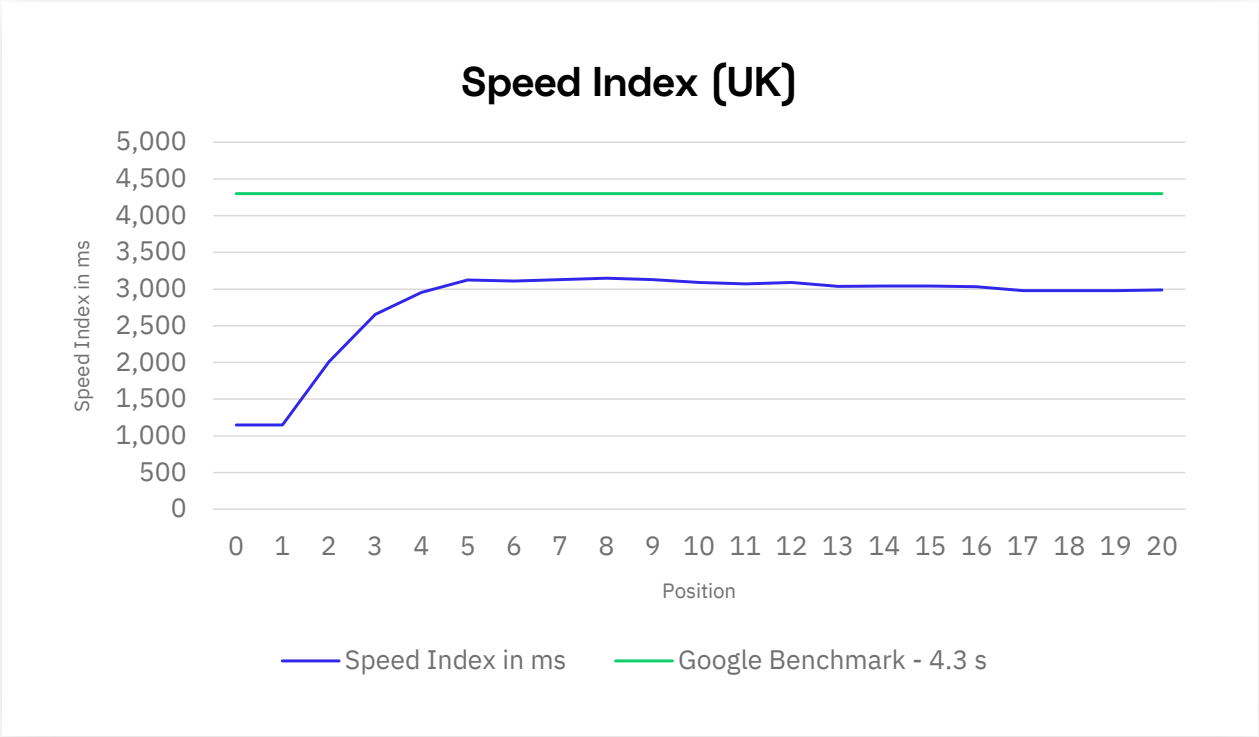
1.98 sec 10.82 sec

53.9% faster than Google's benchmark of 4.3 seconds.

Top 20 average

2.80 sec 11.43 sec

34.8% faster than Google's benchmark of 4.3 seconds.



Unused CSS Results

Top 5 average

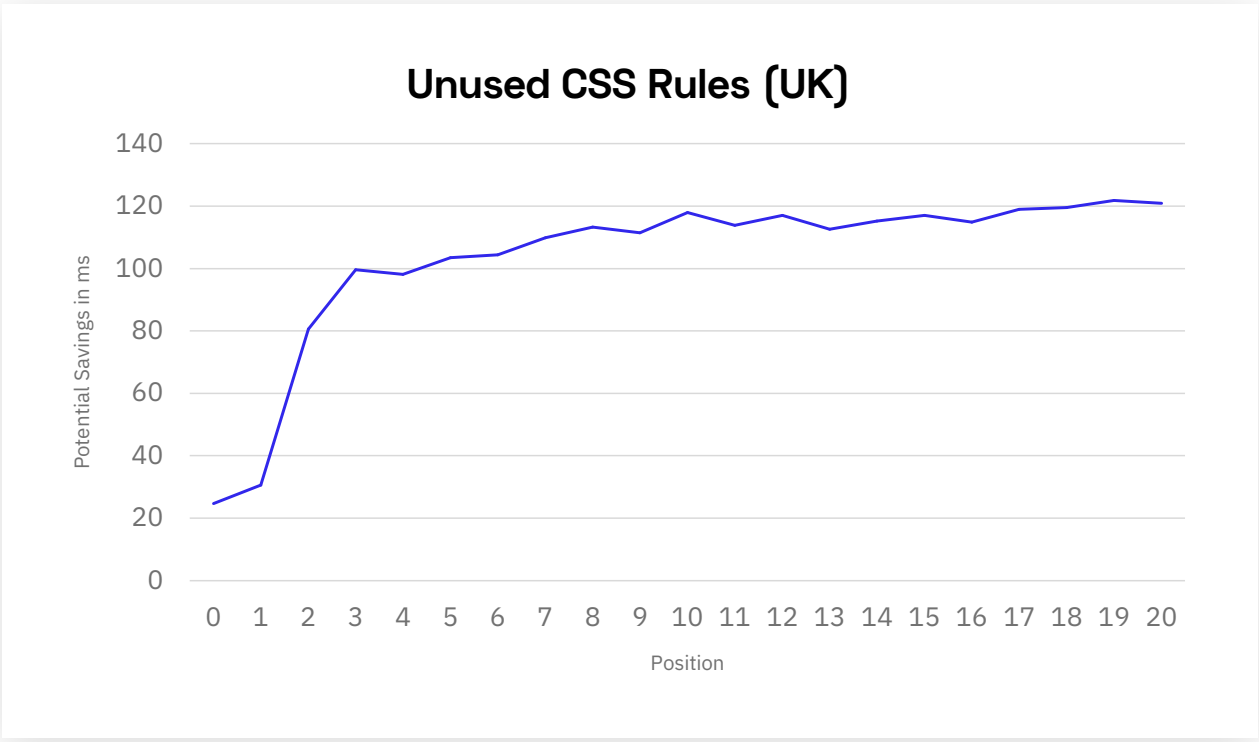
67 ms

490 ms

Top 20 average

103 ms

500 ms



Unused JavaScript Results

Top 5 average

866 ms **3.29** sec

Top 20 average

908 ms **3.74** sec

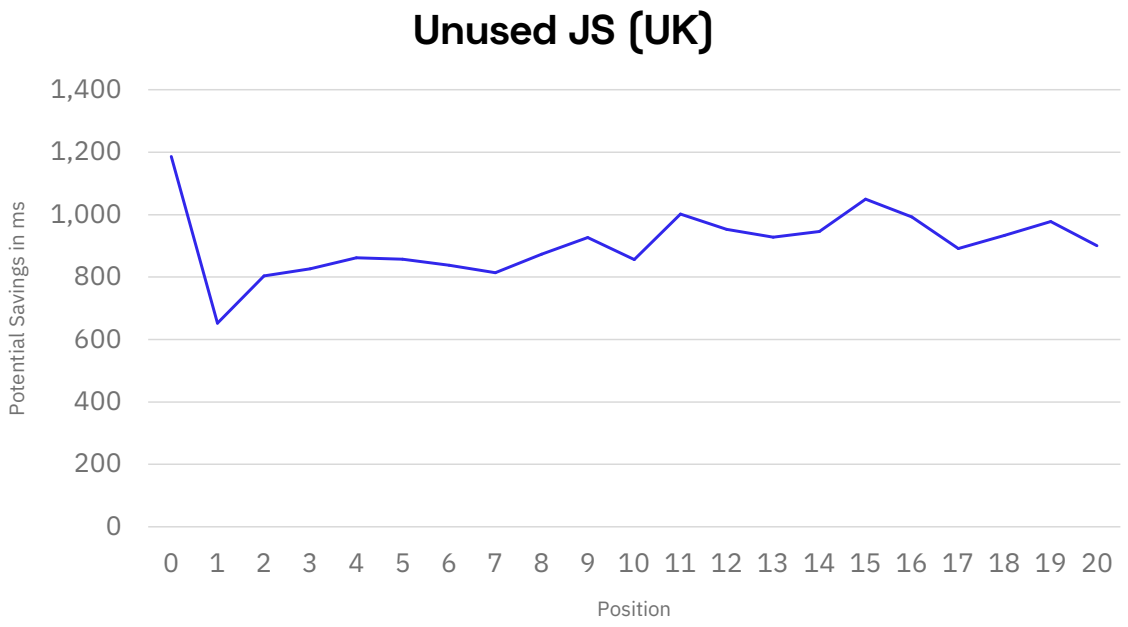


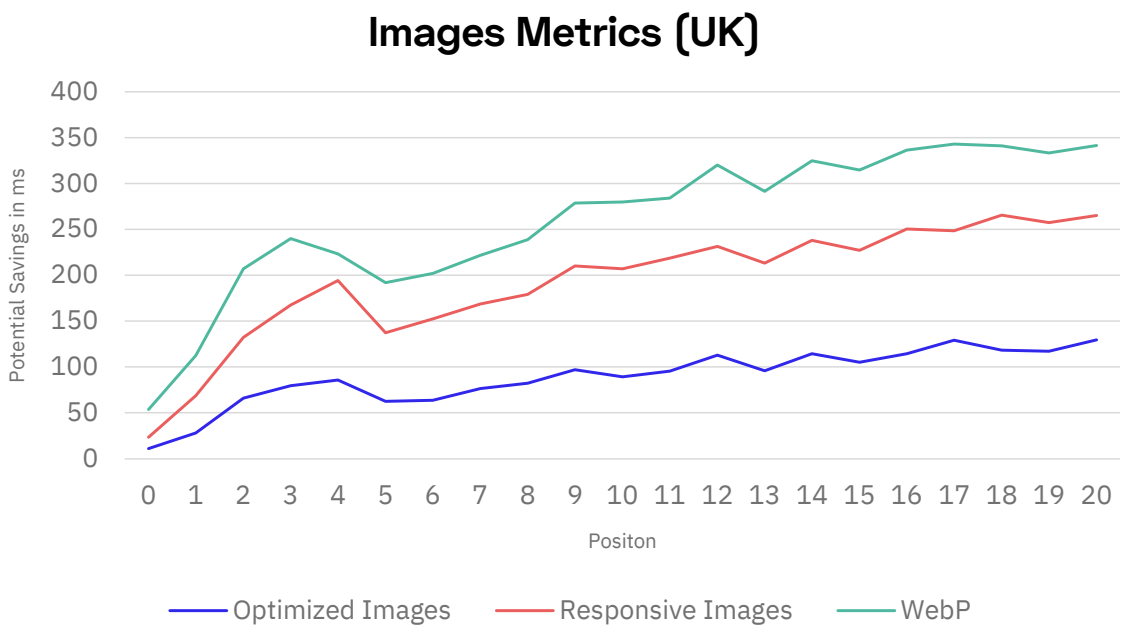
Image Metric Results

Top 5 average

Optimized Images	54 ms	606 ms
Responsive Images	117 ms	824 ms
WebP Images	167 ms	1.84 sec

Top 20 average

Optimized Images	89 ms	615 ms
Responsive Images	193 ms	733 ms
WebP Images	260 ms	1.73 sec



DOM Size Results

Top 5 average

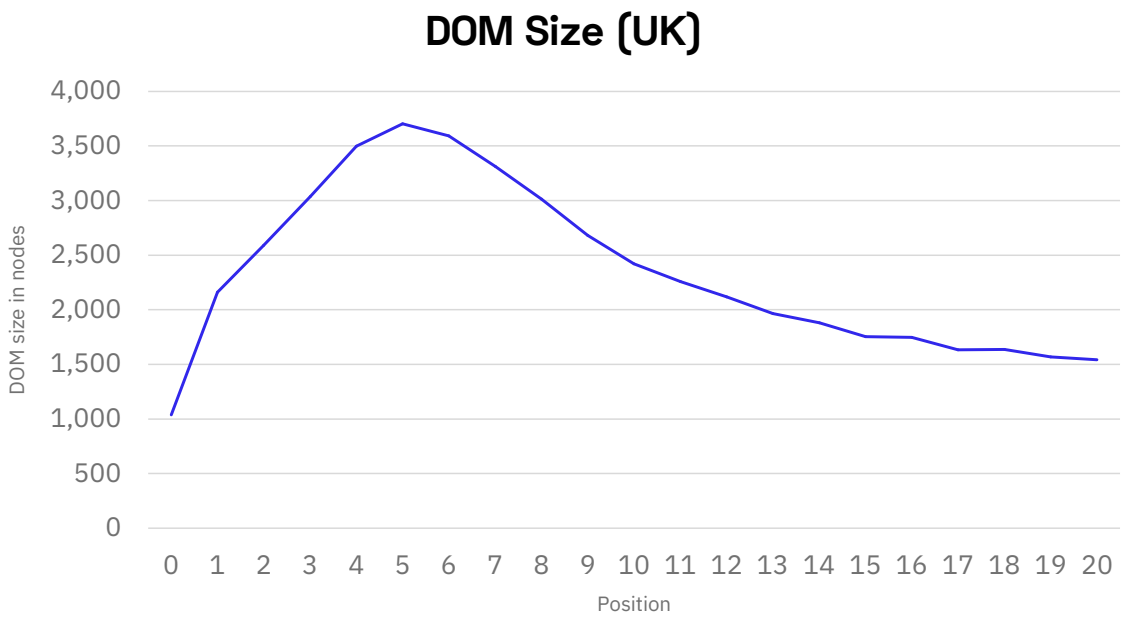
2463 nodes **1226** nodes

64.2% larger than Google's benchmark of 1500 nodes.

Top 20 average

2340 nodes **1237** nodes

56.0% larger than Google's benchmark of 1500 nodes.



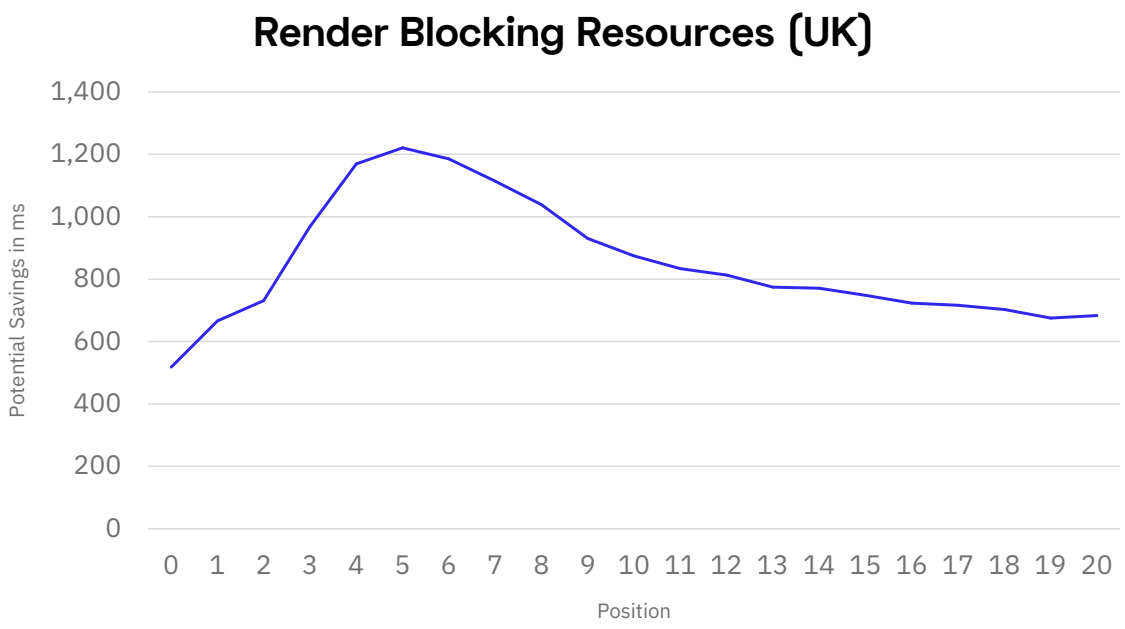
Render Blocking Resources Results

Top 5 average

810 ms **1.33** sec

Top 20 average

850 ms **1.35** sec



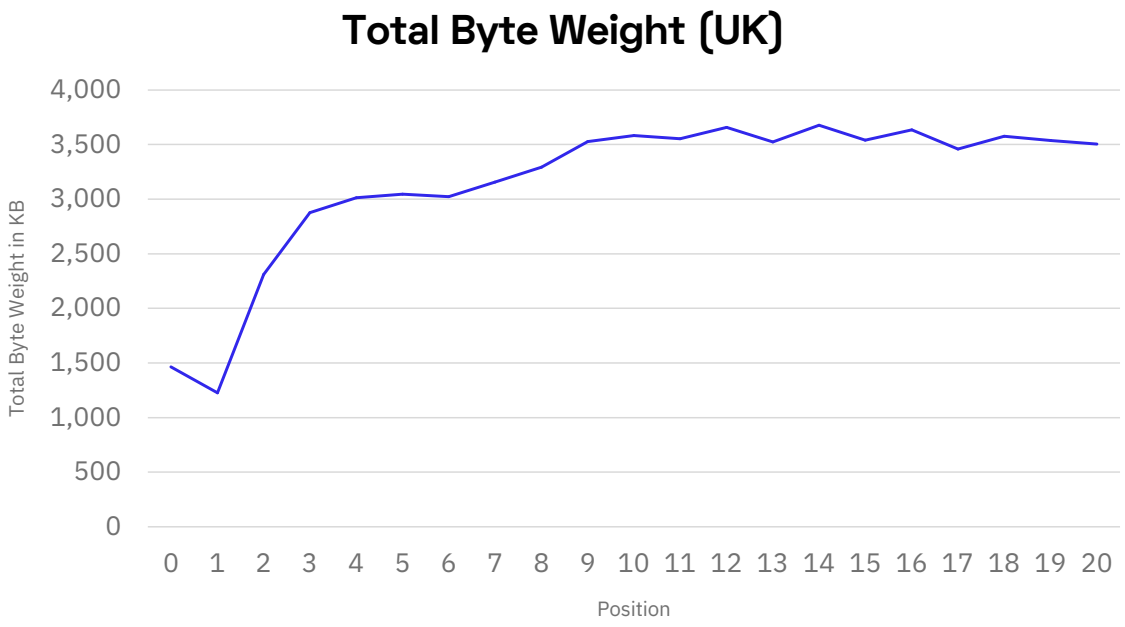
Total Byte Weight Results

Top 5 average

2178 KB 3346 KB

Top 20 average

3151 KB 3710 KB



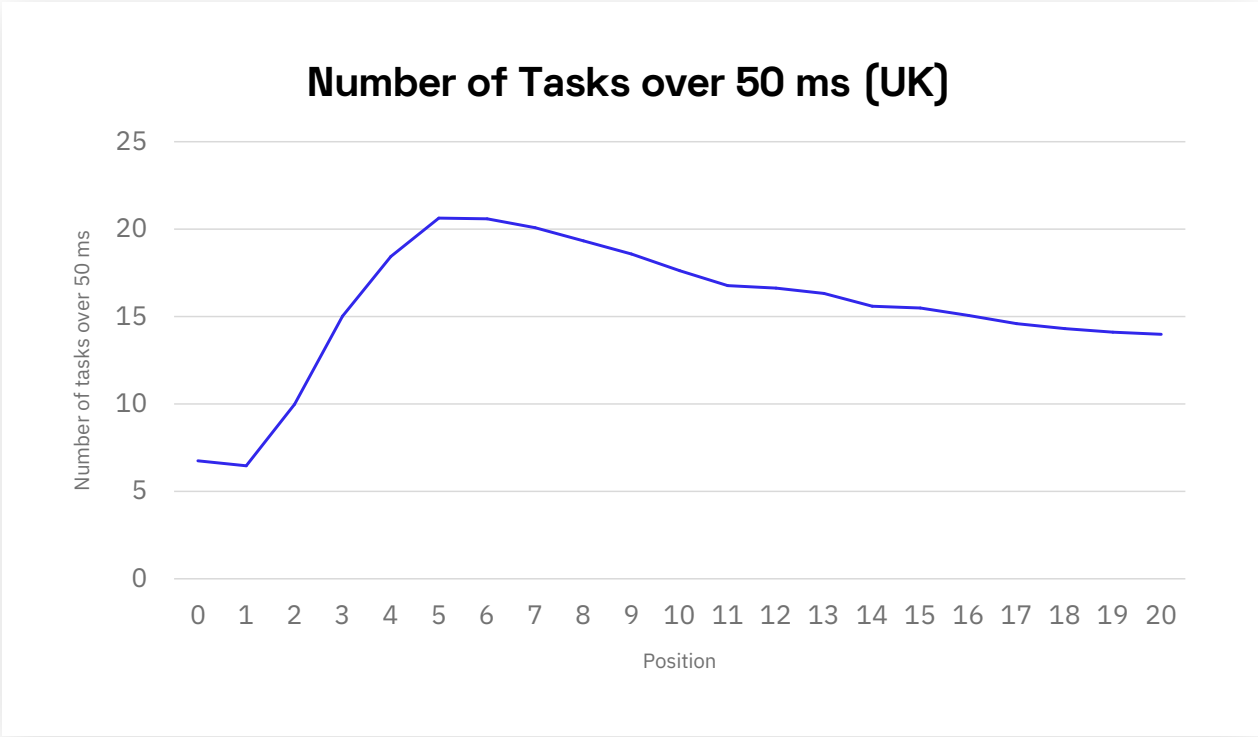
Number of Tasks over 50ms Results

Top 5 average

11.3 16.84

Top 20 average

15.5 17.46



Methodology

In total, we crawled over 2 million URLs. This is based on the top 20 organic Google search results for for three countries: the USA, UK and Germany. The German data will be presented in a separate edition of this study. The keywords were filtered based on relevance and the regional keyword sets were kept as distinct as possible.

We chose to analyze performance data for desktop and mobile but focus mainly on the desktop results. **Even though Google indexes mobile-first we believe the desktop benchmarks provide more useful targets to aim for.** Google's Core Web Vitals tests for mobile use throttled data and as such the results are much higher.

Core Web Vitals and other performance metrics were measured by accessing the PageSpeed[22] and Lighthouse[23] APIs.

Once we had gathered the data, we performed a correlation analysis to calculate a correlation coefficient for each ranking factor. **Simple averages for the top 20 and top 5 positions were calculated per metric, as well as how close these values are to Google's benchmarks.**

Total Blocking Time was used as a proxy for First Input Delay. If a user does not interact with a page, this results in an FID score of 0. Rather than filter these 0 values out, we believed a more accurate reflection is to look at all webpages, hence TBT was selected as a proxy (this is also the proxy metric Google recommends).

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Endnotes

[1] Google: https://developers.google.com/search/blog/2021/04/more-details-page-experience

[2] Google: https://developers.google.com/search/blog/2020/11/timing-for-page-experience

[3] Google: https://web.dev/vitals/

[4] Google: https://developers.google.com/search/blog/2021/04/more-details-page-experience

[5] Google: https://developers.google.com/search/docs/guides/page-experience

[6] Useful resource: https://web.dev/vitals-tools/

[7] Google: https://web.dev/vitals/

[8] Google on throttling mobile data: https://github.com/GoogleChrome/lighthouse/blob/master/docs/throttling.md

[9] Google: https://web.dev/fid/

[10] Google: https://developers.google.com/search/blog/2021/04/more-details-page-experience

[11] Google: https://web.dev/optimize-lcp/

[12] A useful Google article on how to optimize video loading: https://web.dev/lazy-loading-video/

[13] Google: https://web.dev/tbt/

[14] Google: https://web.dev/cls/

[15] Google: https://web.dev/tti/

[16] Google FCP reference: https://web.dev/first-contentful-paint/

[17] Lighthouse audit tool: https://developers.google.com/web/tools/lighthouse

[18] Chrome Dev Tools: https://developers.google.com/web/tools/chrome-devtools

[19] Chrome Dev Tools: https://developers.google.com/web/tools/chrome-devtools

[20] Google WebP image format: https://developers.google.com/speed/webp

[21] Google: https://web.dev/tbt/

[22] PageSpeed API starter guide: https://developers.google.com/speed/docs/insights/v5/get-started

[23] Lighthouse starter guide: https://developers.google.com/web/tools/lighthouse/

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